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Hanford Site Background:

Part 3, Groundwater Background



United States
Department of Energy
Richland, Washington

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Hanford Site Background: Part 3, Groundwater Background

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EXECUTIVE SUMMARY

This report presents and interprets groundwater background data collected from the unconfined aquifer beneath the Hanford Site, a U.S. Department of Energy complex located near Richland, Washington. Characterization of background composition is an important component of environmental characterization activities and serves as a basis for distinguishing the presence and significance of contamination. Background data can also be used to assess the levels of baseline risk to which humans or other receptors are typically exposed and to establish remediation goals. Evaluating background on a sitewide basis provides a consistent, technically defensible definition of background as opposed to determining area-specific background compositions for each waste management unit being considered for remediation across the Hanford Site.

The determination of natural background concentrations requires the use of representative groundwater data unaffected by onsite operations. Two sources of data used in this report were: (1) historical data gathered in conjunction with monitoring activities, and (2) data collected specifically for the purpose of evaluating groundwater background.

The historical data were screened to eliminate samples and/or constituents that may have been affected by Hanford Site activities. The screening process was conducted in two steps: (1) using thresholds based on an upper range of background compositions to eliminate any data which show obvious signs of contamination, and (2) evaluating the location of each well with respect to known groundwater contamination and area activities.

Samples obtained specifically for evaluating background were collected from existing wells demonstrated to be free of contaminants and from wells situated in areas that had little pre-existing data associated with them. A fundamental data quality objective for well selection was to maximize the lateral coverage of groundwater across the Hanford Site. Most new groundwater analyses were conducted in laboratories at Pacific Northwest National Laboratories (PNNL) in Richland, Washington, using techniques that produced detection limits lower than those associated with routine analyses. Data from the new samples were closely examined for the presence of outliers that could be considered contaminants; data that failed this screening process were censored from the final data set. The historical and new data sets were evaluated independently with respect to detection limits, number of data per analyte, and summary statistics. Comparing the two data sets shows that the new data have considerably lower detection limits for most analytes; this is particularly true for radionuclides.

Summary statistics computed from these data are compiled in Table ES-1. This table shows the geometric mean, standard deviation, minimum and maximum values, and the 90th and 95th percentiles computed for a lognormal distribution. These different statistics have been presented to facilitate the use of background information for different needs. For example, if background is used as a cleanup criterion under the *Washington Administrative Code* (WAC) 173-340 (the *Model Toxics Control Act* [MTCA]), then the 90th percentile of the lognormal distribution is relevant. Statistical values used for constituent screening in risk assessment are typically the geometric mean or an upper percentile (e.g., 90th or 95th). An alternative to using a single number for background is to use a statistical test or tests that compare all of the data from the background

set with all of the data from the area being evaluated to determine, for example, if there is a statistically significant difference between the means of the two data sets.

A comparison of background values to cleanup criteria for selected analytes is presented in Table ES-2. This table illustrates two important facets of the background study: (1) the significance of the new data with respect to the old (largely due to the lower detection limits of the new data), and (2) the exceedence of one or more regulatory standards by background values for seven analytes. The latter is important in groundwater remediation because all regulations recognize background as the default cleanup limit if calculated or tabulated cleanup values fall below background. For example, the MTCA "B" cleanup limit for arsenic in groundwater is more than two orders of magnitude below background levels at the 90th percentile.

The data presented in this report represent the most comprehensive evaluation of the range of groundwater compositions from the upper unconfined aquifer. Applications of the background data include their use as screening criteria for evaluating groundwater contamination and as possible cleanup limits. It is recommended that the data presented in this report be used for all appropriate applications concerning groundwater background compositions on the Hanford Site.

Table ES-1. Selected Summary Statistics for Groundwater Background (Page 1 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Alkalinity	New	More data	Unfiltered	µg/L	118650	1183	30	80000	170000	147127	156367
Aluminum	New	Lower DL	Filtered	µg/L	1.23	3.92	32	0.5	187	7.13	11.7
Americium-241*	New	Lower DL	Filtered	fCi/L	0.732	2.11	16	0.05	1	0.077	0.08
Ammonia	New	Lower DL	Unfiltered	µg/L	26.2	3120	32	5	882	113	170
Antimony	Historical	No new	Filtered	µg/L	23.8	1.92	15	9.47	53.9	55.1	69.8
Antimony-125	New	Lower DL	Filtered	fCi/L	3.77	1.61	17	1.73	8.97	0	0
Arsenic	New	Lower DL	Filtered	µg/L	1.83	3.11	29	0.5	8.81	7.85	11.8
Barium	New	Lower DL	Filtered	µg/L	31.2	2.58	32	0.5	94.1	105	149
Beryllium	Historical	More > DL	Filtered	µg/L	0.583	2.91	17	0.2	2.5	2.29	3.38
Beryllium-7	Historical	No new	Unfiltered	pCi/L	6.42	1.26	4	5.25	8.3	8.64	9.4
Boron	Historical	No new	Filtered	µg/L	20.3	1.56	7	12.6	45	36	42.3
Bromide	New	Lower DL	Unfiltered	µg/L	61.9	1721	32	15	235	124	151
Cadmium	New	Lower DL	Filtered	µg/L	0.274	2.57	32	0.05	0.5	0.916	1.29
Calcium	Historical	More data	Unfiltered	µg/L	36518	1.33	25	19200	79683	52644	58389
Cesium-134	Historical	No new	Unfiltered	pCi/L	0.747	1.39	4	0.496	1.06	1.13	1.28
Cesium-137	New	Lower DL	Filtered	fCi/L	2.26	2.79	17	0.643	29.5	8576	58732
Chloride	Historical	More data	Unfiltered	µg/L	7052	1.86	27	1139	21950	15630	19580
Chromium	New	Lower DL	Filtered	µg/L	0.893	2.16	27	0.5	4.41	2.4	3.17
Cobalt	New	Lower DL	Filtered	µg/L	0.274	2.57	32	0.05	0.5	0.916	1.29
Cobalt-60*	New	Lower DL	Filtered	fCi/L	1.09	2.43	17	0.404	23	22.5	44.7
Conductivity	Historical	More data	Unfiltered	mS/cm	348	1.41	35	150	1361	541	614
Copper	New	Lower DL	Filtered	µg/L	0.332	2.01	32	0.05	0.5	0.81	1.04
Cyanide	New	No Historical	Unfiltered	µg/L	5.43	1407	25	5	26.7	8.41	9.32
DO	New	No Hist.	Unfiltered	µg/L	5306	2117	31	380	9440	13877	18218
Eh	New	No Hist.	Unfiltered	mv	315	1.38	31	91	510	476	535
Europium-152	New	Lower DL	Filtered	fCi/L	12.9	1.51	17	5.39	24.1	222128	5620950
Europium-154	New	Lower DL	Filtered	fCi/L	8	1.52	17	3.43	18.3	69517	751469

Table ES-1. Selected Summary Statistics for Groundwater Background (Page 2 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Europium-155	New	Lower DL	Filtered	fCi/L	2.33	1.87	17	0.969	11.7	5932	35471
Fluoride	Historical	More data	Unfiltered	µg/L	491	1.8	28	267	5850	1047	1298
Gross alpha	New	More data	Filtered	pCi/L	1.09	2.03	19	0.25	3.02	0	0
Gross beta	New	More data	Filtered	pCi/L	5.6	1.33	19	3.39	9.45	3.1	4.15
Iodine	New	No Hist.	Unfiltered	µg/L	250	1000	25	250	250	250	250
Iodine-129	New	Lower DL	Filtered	aCi/L	28.8	2.51	9	6.3	96.1	0.9	0.95
Iron	Historical	More data	Filtered	µg/L	55.3	6.17	22	6	7225	570	1104
Lead	New	Lower DL	Filtered	µg/L	0.271	2.59	31	0.05	0.5	0.917	1.3
Lithium	New	More data	Unfiltered	µg/L	5729	1701	30	2380	19000	11321	13729
Magnesium	New	More data	Filtered	µg/L	11245	1.85	25	825	39600	24816	31051
Manganese	New	More data	Filtered	µg/L	2.22	9.25	32	0.05	94.4	38.5	86.4
Mercury	New	Lower DL	Filtered	µg/L	0	5.34	27	0	0.012	0.003	0.006
Molybdenum	New	Lower DL	Filtered	µg/L	0.862	2.79	25	0.5	11.6	3.21	4.67
Nickel	New	Lower DL	Filtered	µg/L	0.686	1.9	31	0.27	2.56	1.56	1.98
Nitrate	New	More data	Unfiltered	µg/L	5681	3361	26	85	28063	26871	41723
Nitrite	New	More data	Unfiltered	µg/L	29.2	2483	32	10	629	93.7	130
Oxalate	New	No Hist.	Unfiltered	µg/L	161	1566	32	95	280	287	338
pH	Historical	More data	Unfiltered	0	7.78	1.04	35	6.94	8.79	8.23	8.36
Phosphate	New	Lower DL	Unfiltered	µg/L	102	1432	32	65	293	162	184
Plutonium	New	No Hist.	Filtered	µg/L	0038	2.15	25	0.001	0.005	0.01	0.013
Plutonium-238	New	Lower DL	Filtered	fCi/L	0.064	2.64	16	0.015	0.485	0.499	0.532
Plutonium-239/240	New	Lower DL	Filtered	fCi/L	0.398	1.97	16	0.04	0.762	0	0
Potassium	Historical	No new	Unfiltered	µg/L	4578	1.71	25	768	10000	9122	11089
Potassium-40	Historical	No new	Unfiltered	pCi/L	77.3	2.12	10	12	188	203	266
Radium-226	New	Lower DL	Filtered	fCi/L	18.2	1.6	17	7	41.5	1063	5179
Radium-228	New	Lower DL	Filtered	fCi/L	32.3	1.72	17	12.8	75.6	0	0

Table ES-1. Selected Summary Statistics for Groundwater Background (Page 3 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Ruthenium-106	New	Lower DL	Filtered	fCi/L	1.63	1.89	17	0.607	5.92	128447	3061043
Selenium	New	Lower DL	Filtered	µg/L	0.96	6.47	32	0.05	11.6	10.5	20.7
Silicon	Historical	No new	Filtered	µg/L	13691	2.03	7	2966	23900	33949	43904
Silver	Historical	No new	Filtered	µg/L	3.42	1.41	15	1.93	5	5.28	5.98
Sodium	Historical	More data	Unfiltered	µg/L	13402	1.73	25	2360	32000	26998	32919
Strontium (elemental)	New	More data	Filtered	µg/L	158	1.75	32	13.1	402	323	396
Strontium-90	New	Lower DL	Filtered	fCi/L	4.78	2.39	14	0.641	15.6	1.03	1.14
Sulfate	New	More data	Unfiltered	µg/L	27102	1537	28	11190	71212	47014	54950
Sulfide	New	More data	Filtered	µg/L	1.71	1.21	32	1.6	3.21	2.19	2.35
Technetium-99	Historical	No new	Unfiltered	pCi/L	0.447	1.62	5	0.271	0.752	0.83	0.988
Thallium	Historical	No new	Filtered	µg/L	1.14	1.35	4	0.883	1.73	1.67	1.87
Thorium	New	No Hist.	Filtered	µg/L	0.5	1	25	0.5	0.5	0.5	0.5
Tin	Historical	No new	Filtered	µg/L	15.9	1.27	12	11.8	31.3	21.6	23.6
Titanium	Historical	No new	Filtered	µg/L	30	1	7	30	30	30	30
Total carbon	New	No Hist.	Unfiltered	µg/L	30325	1174	32	20990	43175	37234	39462
Total dissolved solids	New	No Hist.	Unfiltered	µg/L	200919	1.22	30	140000	295000	258189	277190
Total inorganic carbon	New	More data	Unfiltered	µg/L	28722	1166	32	19550	39020	34955	36953
Total organic carbon	New	No Hist.	Unfiltered	µg/L	1293	1779	32	560	6720	2706	3336
Tritium	Historical	More data	Unfiltered	pCi/L	63.9	1.63	15	27.8	131	119	142
Uranium	New	More data	Filtered	µg/L	2.57	2.85	25	0.5	12.8	9.85	14.4
Uranium-234	Historical	No new	Unfiltered	pCi/L	0.75	1.1	2	0.7	0.803	0.849	0.88
Uranium-235	New	Lower DL	Filtered	fCi/L	23.1	3.34	17	1.55	114	0	0
Uranium-238	New	Lower DL	Filtered	fCi/L	721	1.89	17	150	2440	0	0
Vanadium	New	Lower DL	Filtered	µg/L	1.83	4.19	32	0.5	16.7	11.5	19.3

Table ES-1. Selected Summary Statistics for Groundwater Background (Page 4 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Zinc	New	Lower DL	Filtered	µg/L	1.27	9.22	32	0.05	1270	21.8	48.9
Zirconium	Historical	No new	Filtered	µg/L	25	1	7	25	25	25	25

Shading indicates that > 50% of the data below detection limit.

* Assume value of zero, as this is a Hanford Site contaminant not found in fallout.

DL = Detection Limit

µg/L = micrograms per liter

pCi/L = picocuries per liter

fCi/L = femtocuries per liter (10^{-3} pCi/L)

aCi/L = attocuries per liter (10^{-6} pCi/L)

mS/cm = millisiemens per centimeter

Table ES-2. Comparison of Groundwater Background Values to Regulatory Standards

Analyte	Units	Historical Data		New Data		Regulatory Standards			
		90th Percentile	Maximum	90th Percentile	Maximum	MCL	MTCA B	State GWQ	AWQC
Antimony	µg/L	55	53.9	nd	nd	6	6.4		
Arsenic	µg/L	7.1	8.2	7.8	8.8	50	0.05		0.018 ^b
Beryllium	µg/L	2.3	2.5	0.9	0.5	4	0.0203		5.3 ^b
Chromium	µg/L	6.6	6.0	2.4	4.4	100	80	50	11 ^b
Lead	µg/L	2.4	2.2	0.92	0.5		5 ^a	50	1.78 ^c
Mercury	µg/L	0.12	0.15	0.003	0.012	2	4.8	2	0.012 ^c
Radium-226	pCi/L	nd	nd	1.98	0.094			3	
Selenium	µg/L	6.0	5.1	12.0	11	50	80	10	5 ^c
Thallium	µg/L	1.7	1.7	nd	nd	2	1.12		

Values that are shaded exceed one or more groundwater regulatory limits.

^a No *Model Toxics Control Act* (MTCA) Method B value; use MTCA Method A.

^b Federal Ambient Water Quality Criteria (AWQC) (40 CFR 131)

^c State Ambient Water Quality Criteria (AWQC)(WAC 173-201A-040)

GWQ = Washington State Groundwater quality Standards (WAC 173-200-040)

MCL = Safe Drinking Water Act Maximum Contaminant Level (40 CFR 141)

MTCA = MTCA Method B groundwater cleanup standard (WAC 173-340-7209(b) in Ecology publication #94-145, updated January 1996)

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ACRONYMS

BLVWS	Battelle large volume water sampler
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
CRBG	Columbia River Basalt Group
DOE	U.S. Department of Energy
DQO	data quality objective
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
HEIS	Hanford Environmental Information System
ICP/AES	inductively coupled plasma atomic emission spectrometry
ICP/MS	inductively coupled plasma mass spectrometer
MTCA	<i>Model Toxics Control Act</i>
NTU	nephelometric turbidity unit
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
QC	quality control
RCRA	<i>Resource Conservation and Recovery Act of 1976</i>
USGS	U.S. Geological Survey
WAC	<i>Washington Administrative Code</i>
WHC	Westinghouse Hanford Company
WMU	waste management unit

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1.0 INTRODUCTION

This report evaluates the levels of naturally occurring inorganic chemicals and radionuclides in the uppermost unconfined aquifer at the Hanford Site, a U.S. Department of Energy (DOE) complex located near Richland, Washington. Information contributing to this evaluation is from both historical data and new data collected specifically for the purpose of characterizing groundwater background.

The term "background" generally refers to the composition of a medium unimpacted by activities at a waste management unit (WMU) at either a *Resource Conservation and Recovery Act of 1976* (RCRA) or a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) site (WHC 1991). Natural background is defined by the U.S. Environmental Protection Agency (EPA) as the ambient concentration of chemicals in the environment unimpacted by human activities. The concentration of chemicals consistently present in the environment due to human activities that is not site-specific is defined as "natural background" by the Washington State Department of Ecology (Ecology) (*Washington Administrative Code* [WAC] 173-303). Background as used in this document is intended to be consistent with the Ecology definition of natural background. Using this definition, anthropogenic background levels attributable to non-Hanford Site human activities (e.g., contaminants resulting from offsite agricultural activities) are included as background.

Constituents that are not considered as background include organic compounds and radionuclides that were predominately employed in or were a by-product of Hanford Site operations. These constituents include organic halides and isotopes such as cobalt-60 and americium-241. Some of these constituents were used in the screening process to exclude contaminated samples from the background database.

Groundwater background composition is important in environmental remediation and closure activities associated with CERCLA and RCRA sites. Establishment of background groundwater concentrations at the Hanford Site can serve as a site-specific basis for defining contamination, as a baseline for assessing protection to human health and the environment, and in establishing remediation goals (e.g., EPA 1986, WAC 173-303 and 173-340).

When the background composition is known, it can be used to identify contaminated media as those media having concentrations of constituents that exceed background. The natural range of chemical concentrations is also used in risk assessment activities to (1) act as the primary screening parameter and (2) define the levels of human and ecosystem exposure to chemicals that are normal for the site or region. Thus, background compositions provide a lower bound for levels of contaminants that are harmful to humans and the environment because background concentrations generally are not regarded as harmful (EPA 1989a). Characterization of background has the added benefit of providing a scientific basis to justify avoiding unnecessary expenditure of resources on remediation efforts of the natural environment.

Essentially all of the inorganic constituents measured in groundwater in accordance with analytical protocols (e.g., SW-846 [EPA 1986] and the contractor laboratory program [EPA 1989b]) occur naturally at some level. The major inorganic constituents in groundwater (>5 milligrams per liter) are calcium, magnesium, silicon, sodium, chloride, and sulfate (Freeze and Cherry 1979). These constituents comprise over 90 percent of the total dissolved solids in most water. Barium, iron, manganese, potassium, strontium, carbonate, fluoride, and nitrate are common minor constituents (0.01 to 10 milligrams per liter). Most other components occur as trace constituents (<0.1 milligram per liter). The constituents of greatest concern for groundwater background are those that are also regarded as dangerous waste constituents and that occur naturally at levels high enough to be mistaken for contaminants. Characterization of the background levels are particularly important at sites where the natural constituent concentrations are high (i.e., compared to drinking water levels). The extent to which elevated constituent concentrations in groundwater exist and can be verified is a subject of much interest and is the main focus of this report.

This report builds on the development and refinement of a conceptual model and experimental data presented in previous reports (WHC 1991; DOE-RL 1992). The intent of this report is to provide natural groundwater background compositions that can be used to assess environmental restoration activities at the Hanford Site. This is accomplished in the following general steps:

- Identify the sources of existing and/or available data
- Develop screening criteria to determine the extent to which the available data can be used for defining background
- Screen the available data using these criteria to produce a data set that unequivocally represents natural background
- Use knowledge from the wells selected as representative background to choose candidate wells for the specific purpose of obtaining new data to characterize background
- Document compositional characteristics
- Summarize the findings and results of groundwater background at the Hanford Site and discuss some of the statistical methods for evaluation of the data.

The data quality objectives (DQOs) that pertain to the characterization of groundwater background are identified in Chapter 2.0 together with an overview of the site-wide approach for characterizing groundwater background. The DQOs are important because they help ensure that the data used are appropriate for their intended purposes. A summary of the conceptual model developed to explain the controlling factors of groundwater composition at the Hanford Site and an overview of the hydrologic framework are presented in Chapter 3.0. The sources of information and data that are presently available are identified in Chapter 4.0. The use and limitations of the data and the criteria used to screen these data are also summarized in Chapter 4.0. The compositional characteristics of groundwater background based on the screened data set

and an evaluation of these data in terms of the conceptual model are presented in Chapter 5.0. A summary of findings and the conclusions resulting from this report are presented in Chapter 6.0. References used throughout the document are listed in Chapter 7.0.

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2.0 STUDY OBJECTIVES AND THE HANFORD SITEWIDE APPROACH CHARACTERIZATION OF GROUNDWATER BACKGROUND

The following sections address the objectives of this study, the intended use of the data, and the Hanford Sitewide approach to characterization of groundwater background.

2.1 OBJECTIVES AND USE OF DATA

The primary objective of this study is to characterize the range of groundwater compositions that exist naturally in the unconfined aquifer beneath the Hanford Site. Data considered in this report include all chemical and radiological constituents that are, or may be, important contributors to background. Specifically excluded from the data set are constituents that could only have come from Hanford Site activities. Constituents that occur in natural groundwater and that may have been elevated by Hanford Site activities (e.g., uranium) are carefully evaluated to screen out Hanford Site-related contamination. The data used in this characterization effort must also account for spatial differences in groundwater composition across the Site, which includes lateral distance from surface recharge areas.

These data are to be used primarily as a baseline for defining groundwater contamination and for evaluating the significance of contamination, including the assessment of risk to human health. The data will also be used to guide the decisions and activities for environmental restoration on the Hanford Site.

The primary users of these data are the DOE and its contractors, the environmental regulatory agencies and other government agencies (EPA, Ecology, U.S. Geologic Survey [USGS]), and other organizations involved in the use of groundwater background compositional data at the Hanford Site.

2.1.1 Data Quality Needs

Stringent acceptance criteria were applied to the screening of existing Hanford Site groundwater data. This was done so only data not affected by Hanford operations were used in this evaluation. Although this level of screening severely reduced the amount of data used, the screening yielded a valuable data set that ensured groundwater background threshold levels were based on samples originating from uncontaminated groundwater. The primary criteria used in this screening process were based on the necessity to ensure representative, complete, and comparable data. Because the historical data were collected for other purposes, some DQOs were necessarily emphasized at the expense of others. For example, the DQOs used to ensure that the data were representative of uncontaminated groundwater impacted representativeness and completeness in terms of spatial distribution and coverage. The aspect of representativeness, however, was regarded as inviolate for the purpose of this study. This approach is consistent with the DQO process that uses data to the maximum extent possible.

The general DQO criteria considered in this study focused on the following:

- Lateral and vertical coverage in the unconfined aquifer, with the aim of maximizing spatial coverage
- Numbers and types of samples appropriate for evaluating the various natural process impacts
- Criteria used for selecting background wells, and sampling methodology to employ
- Methods for controlling data quality.

Data from across the Hanford Site obtained from the sources identified in Chapter 4.0 were evaluated and screened against the following specific criteria:

- Groundwater monitoring database samples analyzed since January 1, 1990
- Samples from wells open to the unconfined aquifer
- Wells located away from contaminated plumes or zones of artificial groundwater recharge
- Absence of any anomalously large concentration levels, particularly those of known Hanford Site groundwater contaminants (e.g., nitrate)
- Samples obtained from wells using a submersible pump with prior purging, and using existing sampling procedures
- Groundwater analyses that follow specific analytical protocols.

2.2 CONCEPTUAL MODELS

Two types of conceptual models were developed in conjunction with this effort. The general physical descriptive model for the hydrologic system and its characteristics (DOE 1988) were used as a framework for the flow dynamics of the aquifers beneath the Hanford Site. A qualitative descriptive model in which the chemical composition of groundwater beneath the Hanford Site is expected to change and vary within the aquifer was also developed for this effort (WHC 1991; DOE-RL 1992). This geochemical conceptual model addresses the roles of the many natural processes that influence the composition of the groundwater.

2.2.1 Sitewide Approach to the Characterization of Groundwater Background

The most important DQO for data on groundwater background is that these data represent the range of compositions existing naturally in the unconfined aquifer at the Hanford Site. Because natural variations in groundwater composition exist laterally and vertically on the scale of the aquifer, the information in this report is intended to serve as the baseline for evaluating natural background groundwater concentrations on a sitewide scale.

The most common method of defining groundwater contamination at WMUs is to evaluate the compositions of potentially contaminated groundwater by comparing groundwater compositions from downgradient wells to the composition of groundwater from wells upgradient of the WMU (i.e., local background composition). In general, this unit-based approach is well suited to monitoring waste releases. At the Hanford Site, this unit-based approach results in the establishment of a local reference background for each WMU.

However, several problems occur when using the unit-based approach to establish background for environmental restoration:

- Background levels established at individual WMUs result in multiple definitions of groundwater within the same aquifer. Because groundwater in the unconfined aquifer beneath the Hanford Site is one system, the unit-based approach is scientifically unjustified for determining background on the scale of the aquifer. The problem arising from establishing various unit-based backgrounds is exacerbated where background is defined differently for WMUs that are adjacent or superimposed as when a RCRA treatment, storage, and/or disposal unit is located within or next to a CERCLA operable unit.
- If unit-specific background is used as a reference for defining contamination, then the identification of contamination is inconsistent across the site, as are decisions regarding monitoring or the extent of remediation necessary or feasible.
- Inconsistent identification of contamination and attendant remedial response decisions may result in the inefficient and costly use of resources.
- Inaccurate identification of contamination may occur. Groundwater in upgradient wells, defined as "uncontaminated" from the local WMU perspective, may be contaminated from other operations at the Hanford Site. Using one well upgradient of a WMU may be acceptable for monitoring in some cases, but it is inappropriate for use as natural background.
- Insufficient data exists to characterize the range of compositions that exists naturally within the aquifer or for the scale required for representative sitewide characterization data.

To address these concerns, a sitewide approach to the characterization of groundwater background has been proposed as an alternative to a unit-based background (WHC 1991). The difference between the sitewide and the unit-based approach to characterization of groundwater background is that the data used to establish groundwater background are not restricted to groundwater compositions from upgradient wells at individual WMUs. Instead, to establish groundwater background maxima or thresholds, data from groundwater within the aquifer and on the scale of the aquifer would be used to evaluate the range of compositions that exist naturally within the aquifer. This approach is more appropriate for the characterization of natural background because natural variations in groundwater composition exist on the scale of the aquifer as a result of many natural processes. In general, only groundwater contaminated above the levels of sitewide background would require consideration for risk assessment or remedial action.

The sitewide approach requires the use of data that more accurately represent natural background concentrations. A geochemical model was developed that considers information on the hydrologic framework of the aquifer and on the natural and anthropogenic processes that influence groundwater composition within the aquifer (DOE-RL 1992).

Following are the primary benefits of developing and using a sitewide groundwater background:

- It is a more accurate representation of natural background than could be obtained using data only from site-specific upgradient wells
- It provides a consistent basis for defining groundwater contamination throughout the aquifer, particularly in parts of the aquifer impacted beyond the boundaries of individual WMUs and/or by unknown sources
- It can minimize the misidentification of uncontaminated samples as contaminated, which can occur for some analytes with very low health-based cleanup limits (e.g., arsenic, beryllium); it also reduces the allocation of resources for remediation of contamination within the range of natural background.

Additional discussion on the unit-based and sitewide approaches to the characterization of groundwater background is presented in the following publications: *Characterization and Use of Soil and Groundwater Background for the Hanford Site* (WHC 1991) and *Hanford Site Groundwater Background* (DOE-RL 1992).

2.2.2 Hanford Site Groundwater Conceptual Model

The conceptual model for evaluation of groundwater background for the Hanford Site (WHC 1991) proposed that the groundwater in the unconfined aquifer could be treated as one system. This leads from the observation that materials in the aquifer constitute one natural system (DOE-RL 1995). The primary justifications for this approach follow:

- Natural variations exist in the composition of groundwater within the unconfined aquifer beneath the Hanford Site.
- Compositional variability is due to largely common systematic natural processes that control the distribution and range of compositions throughout the unconfined aquifer.
- Natural variability in groundwater composition occurs laterally and vertically within the aquifer.

The chemical composition of natural water is derived from many different sources of solutes including gases and aerosols from the atmosphere, weathering and erosion of rocks and soil, solution or precipitation reactions occurring below the land surface, and cultural effects resulting from human activities (i.e., anthropogenic background). Groundwater background is a range of compositions resulting from these processes dominated by rock-water interaction (DOE-RL 1992). Because the unconfined aquifer at the Hanford Site is composed of similar materials (DOE-RL 1995), the rock-water reactions that control the hydrochemistry should also be similar. This similarity is used in a conceptual model, which predicts that background in the unconfined aquifer is a range of compositions resulting predominantly from natural processes involving rock-water interaction (DOE-RL 1992).

Influences from non-Hanford Site anthropogenic sources are also included in the definition of natural background. These influences can include components from agricultural activities and global fallout from anthropogenic nuclear activities. Incorporation of radionuclides from global fallout into the unconfined aquifer is complex and poorly understood, as it is dependent on solubility of the radionuclide, recharge source, recharge rate, and hydraulic conductivity across the aquifer.

Because the upper concentration of the range of natural background is very important for environmental restoration, the conceptual model considered the processes of water-rock reaction to be the predominant influence on groundwater composition. These reactions are limited at the maximum range of concentrations by equilibrium conditions, which should cause the concentrations to converge toward largely constant levels.

Lateral and vertical variations in groundwater compositions were also addressed in the groundwater conceptual model. Lateral variations would be predicted to rise as rock-water reactions progress downgradient in the aquifer and compositions converge toward equilibrium. The lowest concentrations of dissolved solids normally would be expected to occur near recharge areas, and the highest concentrations would be expected to occur in waters with the longest residence time in the aquifer (i.e., water farthest downgradient from the recharge zone or water in zones of very low hydraulic conductivity). Vertical variation may be influenced by stratigraphic or structural controls on flow conditions, effects of gases on the composition of the top portion of the aquifer, and mixing with other aquifers and surface waters. A more detailed description of this model is described in the preliminary groundwater background report (DOE-RL 1992).

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3.0 HYDROCHEMICAL PRINCIPLES AND THE HYDROGEOLOGY OF THE HANFORD SITE

This section provides a summary of hydrochemical fundamentals, followed by a brief description of the hydrogeology of the Hanford Site. For those seeking more information on a specific topic, these subjects are discussed in greater detail in other publications, several of which are referenced in the following sections.

3.1 GENERAL CONTROLS ON GROUNDWATER COMPOSITION

The composition of groundwater is controlled by fundamental geochemical properties and principles that operate in all aquifer systems. These fundamentals commonly control the composition of groundwater, which is influenced by site-specific characteristics of the aquifer and the region controlling the aquifer system and its chemistry. Solute concentrations in natural water represent the net effect of a series of chemical reactions that have dissolved material from another phase, have altered previously dissolved components, or have eliminated them from solution by precipitation or other processes (Hem 1989). The types and nature of processes and reactions that typically dominate the composition of natural groundwaters are well understood (e.g., Hem 1989; Freeze and Cherry 1979). However, the relative importance of process within a specific aquifer depends on such site-specific conditions as geology and climate. The site-specific processes influencing the chemical composition of groundwater background within the unconfined aquifer beneath the Hanford Site are summarized here.

Following are the most important of the many components that contribute to natural groundwater compositions:

- Initial composition of the recharge water
- Composition and characteristics of the geologic material encountered
- Type of reactions (e.g., dissolution, oxidation-reduction)
- Degree of reaction completion (i.e., length of time reaction occurs)
- Conditions within the system (e.g., temperature, available oxygen and carbon dioxide, pH, microbial activity).

Most groundwater is recharged from meteoric water (i.e., rain or snowmelt), surface water (i.e., rivers and streams), or springs originating from other aquifers. Meteoric waters typically contain few dissolved solids and have compositions that generally vary with the distance that the water has migrated from its source. Surface waters and springs, however, usually contain higher levels of dissolved solids as a result of reacting with surface materials before entering the subsurface.

The amount of dissolved solids in these surface waters can vary greatly because of the effects of the controlling factors identified previously.

Before entering and recharging an aquifer, most waters react with the rock and/or sediment contacted as the waters pass through the vadose or unsaturated zone. Because geologic materials are the primary source of dissolved solids, reactions between water and these materials, before and after entering the aquifer, are the primary controls on groundwater composition. Each of these geologic solids has a specific chemical composition or range of compositions, as well as specific physical properties that control the nature and extent of their reactions with water. These reactions result in a wide range of concentrations of dissolved inorganic constituents.

Most reactions between water and geologic materials involve dissolution and/or transfer of chemicals from the solid materials into the water. These reactions result in partial or total dissolution of the solid material and/or transformation of the solid into a new secondary solid. There is also an attendant release of certain chemicals into the water. The chemical controls on the type and extent of reaction depend on the composition of the reactants (both water and solid) and the specific conditions under which the reaction occurs. The primary physical controls governing these reactions relate mainly to the conditions of the solid phase, which include the effective surface area and the nature and extent of flow through the media.

The surface area available for reaction and the initial rate of reaction for a porous medium are determined by grain size and the degree of cementation. The surface area and the rate of reaction are determined by the size and number of fractures for a solid nonporous medium. The extent of reaction, which is dependent on the time available for reaction, is determined by the physical characteristics of the aquifer system. These characteristics include porosity, permeability, and hydraulic gradient, which together determine flow rate (hydraulic conductivity). The flow conditions of the system are important for two reasons: (1) the reactions that control groundwater chemistry can vary in extent, type, and sequence depending on the residence time (i.e., the time available for reactions to occur); and (2) water composition resulting from reactions in closed systems differs from compositions in systems where the aquifer system is flushed of early reaction products. These two factors contribute to a series of reactions that occur over time within the aquifer system. Rock-water interaction can, therefore, result in a wide range of groundwater compositions that reflect differences in the physical and/or compositional characteristics between aquifer systems, heterogeneity within aquifer systems, and normal evolution of groundwater with residence time in the aquifer.

Although the chemical characteristics of groundwater in an aquifer system reflect site-specific reaction paths and aquifer characteristics, there are general compositional patterns in most aquifer systems that serve as a basis for understanding rock-water interactions and their role in the evolution of groundwater compositions.

3.2 REGIONAL GEOLOGY AND HYDROLOGY

A framework for understanding the geological controls on the aquifer and their influences on groundwater composition is necessary. Therefore, a brief discussion of the regional geology, the geologic units encountered, and the hydrologic characteristics of the vadose zone and uppermost aquifer beneath the Hanford Site are summarized in this section. A more complete description of the geology and hydrology of the Hanford Site can be found in Delaney et al. (1991).

3.2.1 Regional Geology

The Hanford Site lies in the Pasco Basin, a structural depression bounded by anticlinal ridges on the north, west, and south and a monocline on the east. The Pasco Basin is divided by the Gable Mountain anticline into the Wahluke syncline to the north and the Cold Creek syncline to the south. The Hanford Site is underlain by Miocene-aged basalt of the Columbia River Basalt Group (CRBG) and late Miocene to Pleistocene suprabasalt sediments (Figure 3-1). The sediments thicken into the Pasco Basin and generally reach maximum thicknesses in the Cold Creek syncline along the west-central part of the Hanford Site. Older Cenozoic sedimentary and volcanoclastic rocks underlying the basalts are not exposed at the surface near the Hanford Site.

Most of the late Miocene to Quaternary sediments can be divided into two main groups: rocks belonging to the Ringold Formation and those of the Hanford formation. Plio-Pleistocene sediments occur between the Ringold and Hanford formation sediments in several locations. Quaternary alluvium and wind-blown deposits form a discontinuous veneer over the region. Detailed discussions of the regional setting and Hanford Site geology can be found in DOE (1987 and 1988); Myers et al. (1979);, and Reidel and Hooper (1989) among others. More recently, Delaney et al. (1991) has written a summary of the Hanford Site geology.

3.2.2 Stratigraphy

The following section presents summary descriptions of the geologic units that comprise the stratigraphic sequence at the Hanford Site. Emphasis is placed on materials that occur in the unconfined aquifer, but a brief discussion of rocks and sediments below this aquifer is also presented. A graphic representation of the Hanford Site stratigraphic column is presented as Figure 3-2. A detailed discussion of the Hanford Site stratigraphy is available in Delaney et al. (1991).

3.2.2.1 Geologic Material Beneath the Unconfined Aquifer. The CRBG is present beneath sediments of the unconfined aquifer. The CRBG consists of an assemblage of tholeiitic, continental flood basalts of Miocene age. These flows cover an area of more than 63,000 square miles (163,700 square kilometers) in Washington, Oregon, and Idaho, and have an estimated volume of about 40,800 cubic miles (174,356 cubic kilometers) (Tolan et al. 1989). Isotopic age determinations indicate that the basalt flows erupted approximately 17 to 6 million years ago. More than 98 percent by volume was erupted in a 2.5 million-year period (17 to 14.5 million years ago) (Reidel and Hooper 1989).

Epiclastic and volcanoclastic sediments of the Miocene-age Ellensburg Formation are interbedded with the upper basalt flows. The Ellensburg Formation includes epiclastic sediments deposited by the ancestral Clearwater and Columbia Rivers and volcanoclastic sediment consisting mainly of primary pyroclastic air-fall deposits and reworked epiclastics derived from volcanic terranes west of the Columbia Plateau. A detailed discussion of the Ellensburg Formation at the Hanford Site is provided in Reidel and Fecht (1981). The Rattlesnake Ridge interbed forms the uppermost portion of the Ellensburg Formation. In the central Pasco Basin, the interbed ranges from 1.5 to 15 m (5 to 50 ft) in thickness and is composed of clayey basalt conglomerates, fluvial floodplain deposits, and ash tuffs and tuffites (Graham et al. 1984).

3.2.2.2 Geologic Materials in the Unconfined Aquifer. The Ringold Formation and Hanford formation are the predominant units that compose the unconfined aquifer and vadose zone under the Hanford Site. The fluvial-lacustrine Ringold Formation was deposited by the ancestral Columbia River and its tributaries in response to development of the Yakima Folds during the late Miocene to Pliocene eras (Fecht et al. 1987; DOE 1988). The Ringold Formation at the Hanford Site is up to 185 m (600 ft) thick in the deepest part of the Cold Creek syncline and 170 m (560 ft) thick in the western Wahluke syncline. This formation pinches out against Gable Mountain, Yakima Ridge, Rattlesnake Mountain, and the Saddle Mountains anticlines and is locally absent north of the 200 East Area.

The Ringold Formation consists of semi-indurated clay, silt, pedified mud, fine- to coarse-grained sand, and granule-to-cobble gravel (Newcomb 1958; Newcomb et al. 1972; Myers et al. 1979; Bjornstad 1984; DOE 1988; Lindsey and Gaylord 1989). Recent studies of the Ringold Formation (Lindsey and Gaylord 1989; Lindsey 1991; Lindsey 1995) suggest that the formation is best described and divided based on sediment facies associations and their distribution. Facies associations in the Ringold Formation (defined on the basis of lithology, petrology, stratification, and pedogenic alteration) include fluvial gravel, fluvial sand, overbank deposits, lacustrine deposits, and basaltic gravel.

Overlying the Ringold Formation in the western Cold Creek syncline is a Plio-Pleistocene unit, which is up to 25 m (82 ft) thick and separated into two facies: (1) basaltic detritus and (2) pedogenic calcrete. Depending on the location, one or both facies may be present. The calcrete facies generally consist of interfingering carbonate-rich and carbonate-poor silt and sand. The basaltic detritus facies consist of weathered and unweathered basaltic gravels deposited as locally derived slope wash, colluvium, and side-stream alluvium.

Overlying this Plio-Pleistocene unit in the western Cold Creek syncline is an early Palouse soil that consists of up to 20 m (65 ft) of silt and fine-grained sand (Tallman et al. 1981; Bjornstad 1984; DOE 1988). These strata are very similar to loess deposits in character and are interpreted to be of eolian origin. Underlying the Hanford formation in the east-central Cold Creek syncline and at the east end of Gable Mountain anticline is a sequence of sediments called the pre-Missoula gravels (PSPL 1982). These sediments consist of quartzose-to-gneissic clast-supported pebble-to-cobble gravels with a quartzo-feldspathic sand matrix. The sediments are up to 25 m (82 ft) thick and contain less basalt than the underlying Ringold gravels and overlying Hanford deposits.

Overlying all of these sediments is the Hanford formation that consists of deposits of pebble-to-boulder gravel, fine-to-coarse sand, and silt. Earlier stratigraphic interpretations commonly divided the Hanford formation into two informal members: the Pasco gravels and the Touchet beds (Myers et al. 1979; Tallman et al. 1981; Fecht et al. 1987; DOE 1988). The Pasco gravels generally correspond to the gravelly facies and the Touchet beds to the sandy-to-silty facies. Recent stratigraphic interpretations recognize that these two deposits are divided into three facies, referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies in Baker et al. (1991). The Hanford formation is thickest in Cold Creek in the central portion of the Hanford Site, where it is up to 64 m (210 ft) thick. Hanford formation deposits are absent on ridges at approximately 385 m (1,260 ft) above sea level (Baker et al. 1991).

Holocene surficial deposits consist of silt, sand, and gravel that form a thin (<4.9 m [16 ft]) veneer across much of the Hanford Site. These sediments were deposited by a mix of eolian and alluvial processes.

3.2.3 Hydrology of the Hanford Site

The hydrology of the Pasco Basin (and the Hanford Site, in particular) is characterized by several surface sources and several aquifers, which are associated with both the basalts and the suprabasalt sediments. The basalt aquifers are comprised of the intercalated sediments of the Ellensburg Formation and the permeable zones of individual flows of the CRBG. The uppermost aquifer system is regionally unconfined and is contained largely within the Ringold and Hanford formations. The hydrology of the uppermost aquifer is described in this section. Delaney et al. (1991) provides information on the lower confined aquifers beneath the Hanford Site.

Surface water enters the Pasco Basin via the Columbia River and the Yakima River, both of which adjoin the Hanford Site. Two ephemeral streams, Cold Creek and Dry Creek, are found on the Hanford Site. Water drains along these pathways during the wetter winter and spring months. No perennial streams originate within the Pasco Basin. The total estimated precipitation over the Pasco Basin averages less than 16 cm (6.3 in.) per year. Mean annual run-off is estimated to be less than 3×10^7 cubic meters (2.5×10^4 acre-feet) per year, or approximately 3 percent of the total precipitation. The remaining precipitation is assumed to be lost through evapotranspiration, with a small component (perhaps less than 1 percent) contributing to recharging of the groundwater system (Fayer and Walters 1995).

Major surface-water features associated with the Hanford Site are the Columbia and Yakima rivers. West Lake, about 10 acres (4.0 hectares) in size and less than 0.9 m (3 ft) deep, is the only natural lake within the Hanford Site. In the past, waste water infiltration ponds and ditches associated with nuclear fuel reprocessing activities were present on the Hanford Site. Most of these facilities have been decommissioned as part of the ongoing environmental restoration activities.

The vadose zone at the Hanford Site includes the Holocene surficial deposits, the Hanford formation, and in some areas, portions of the Ringold Formation. In the 100 Areas, the water table is located near the Ringold-Hanford contact, and the vadose zone consists of poorly sorted

gravel, sand, and silt. Beneath the 200 Areas, unsaturated sediments include portions of the Ringold Formation. The vadose zone in the 300 and 1100 Areas consists almost entirely of the Hanford formation. The vadose zone is less than 30 m (100 ft) thick in the areas near the Columbia River and up to 104 m (340 ft) thick beneath the 200 Areas (Hartman 1995).

The uppermost aquifer is unconfined to locally semi-confined and underlies all of the Hanford Site, except where basalt prominences rise above the water table. The water table ranges in depth from surface level at the Columbia and Yakima rivers to 106.7 m (>350 ft) near the center of the Hanford Site. Groundwater within the uppermost aquifer system is contained within the glaciofluvial sands and gravels of the Hanford formation and the fluvial-lacustrine sediments of the Ringold Formation. The position of the water table beneath the western portion of the Hanford Site is generally within the middle Ringold unit. In the northern and eastern portions of the Hanford Site, the water table is generally within the Hanford formation. Hydraulic conductivities for the Hanford formation (609.6 to 3,048 m [2,000 to 10,000 ft] per day) are much greater than those of the middle unit of the Ringold Formation (185.9 to 929.6 m [610 to 3,050 ft] per day) (Law et al. 1987). The effective porosity for the sediments in the unconfined aquifer ranges between 10 and 30 percent (Graham 1981). Stratigraphic divisions of these units and their hydrologic properties are discussed in detail in Delaney et al. (1991).

The uppermost aquifer system ranges to approximately 152.4 m (500 feet) thick near the center of the Cold Creek Syncline. Laterally, the aquifer system is bounded by anticlinal basalt ridges that extend above the water table. On a local scale where the Ringold Formation is present, the silts and clays of the lower Ringold and the fine-grained facies of the basal Ringold form a confining layer. Thus, in the strict sense, the groundwater is unconfined above this layer and semi-confined below it.

The base of the uppermost aquifer is generally regarded to be the Elephant Mountain Member of the CRBG. Erosional windows in the Elephant Mountain basalt confining layer exist locally that may allow hydraulic communication between the Rattlesnake Ridge aquifer and the overlying unconfined aquifer (Graham et al. 1984). A generalized east-west geologic cross-section showing the position of the water table and major stratigraphic units beneath the Hanford Site is presented in Figure 3-3.

3.2.4 Groundwater Recharge and Flowpaths

The general direction of groundwater flow is from the higher elevation natural recharge areas southwest and west of the Hanford Site to discharge areas primarily along the Columbia River. Recharge of the confined basalt aquifers occurs through infiltration on the anticlinal ridges bounding the Pasco Basin and from westward flow in basalt aquifers beneath the Columbia Plateau. Sources of natural recharge to the uppermost (unconfined) aquifer system are infiltration and precipitation run-off on the ridges bounding the Pasco Basin, infiltration from ephemeral streams, and rivers along influent reaches of the Yakima and Columbia Rivers. The contribution of precipitation and its infiltration through the unsaturated (vadose) zone at lower elevations on the Hanford Site has been studied at several test localities. The general conclusion is that very little, if any, infiltration occurs where the soils are relatively fine-grained and normal

vegetation is present (Gee 1987; Routson and Johnson 1990; Rockhold et al. 1990; Fayer et al. 1991; Gee et al. 1992; Fayer and Walters 1995).

Flow rates in the unconfined aquifer vary greatly across the Hanford Site, depending on the physical properties of the aquifer materials. For example, hydraulic conductivity beneath the 200 Areas ranges from less than 1.5 m (5 ft/day) to over 300 m/day (1,000 ft/day) over a scale of several kilometers.

Artificial recharge of the uppermost aquifer system occurs from the disposal of process waste water and sanitary effluent on the Hanford Site, principally in the 200 Areas and from large irrigation projects surrounding the Hanford Site. The water table east of the Columbia River is greatly elevated above the water table west of the river, the result of extensive irrigation in the area east of the Hanford Site. The potential for migration of agricultural contaminants under the Hanford Site because of this head difference in the unconfined aquifer is uncertain.

The effect of process waste disposal on the Hanford Site is illustrated in Figures 3-4 and 3-5. Figure 3-4 is an approximation of the Hanford Site water table in January 1944, before the start of processing operations. Figure 3-5 is a map of the water table beneath the Hanford Site in June 1989, just after the major chemical processing operations were ended. These maps confirm that effluent disposal has altered water table elevations, hydraulic gradients, and groundwater flow directions. Figure 3-6 presents the water table as of June 1995 to illustrate that the water table beneath the 200 Areas continues to fall because of reduced process waste disposal.

During plant operations, the major contaminant sources on the Hanford Site were the process waste disposal facilities in the 100 and 200 Areas. The major contaminant plumes from these areas are delineated by the distributions of tritium and nitrate, the two most mobile contaminants in Hanford Site groundwater. The aerial distributions of the tritium and nitrate plumes on the Hanford Site are shown in Figures 3-7 and 3-8. The tritium and nitrate plumes show the movement of contaminants originating in the 200 East and West Areas and establish the limits of the aquifer considered contaminated. The area outside the nitrate and tritium plumes is considered to represent background chemical composition.

Figure 3-1. General Geology of the Hanford Site

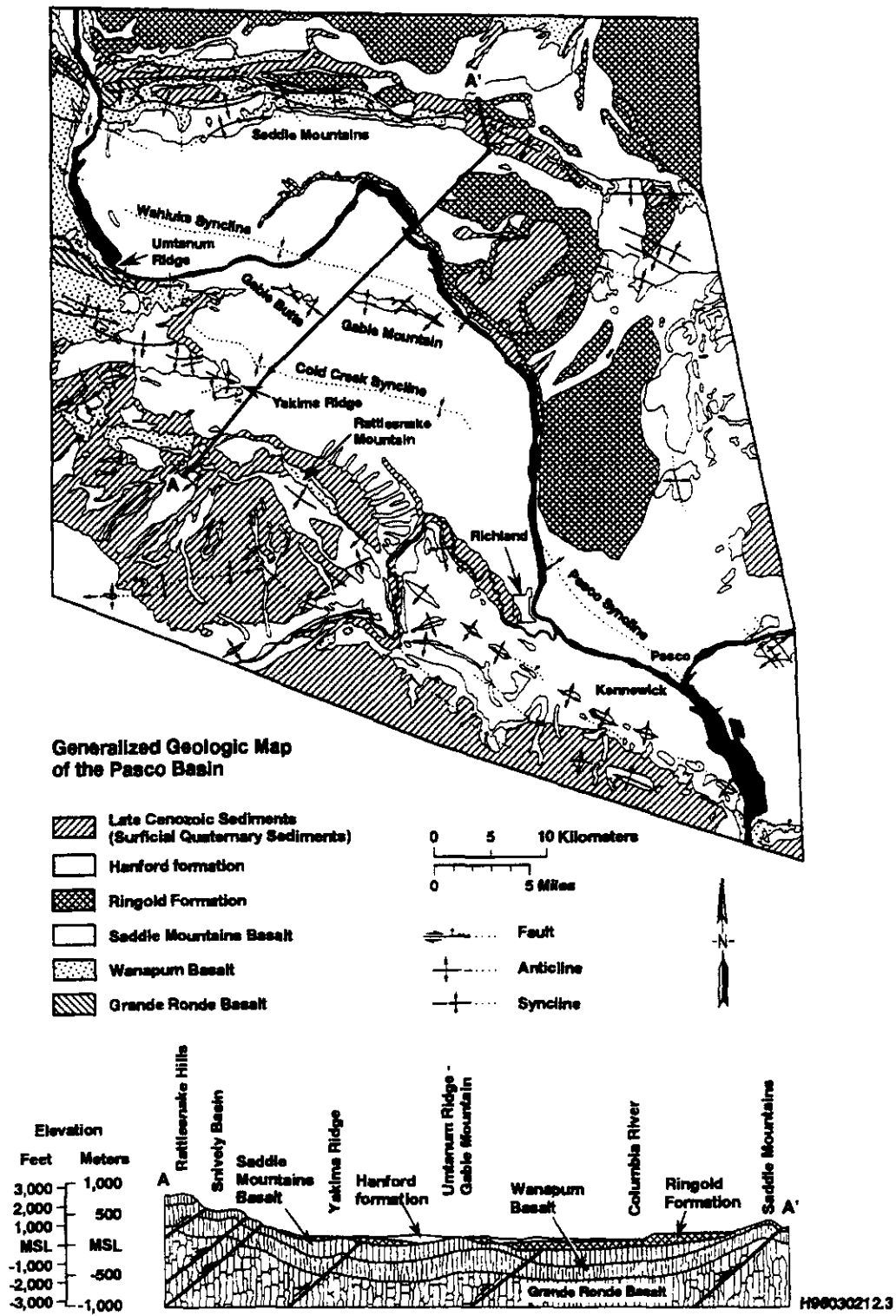
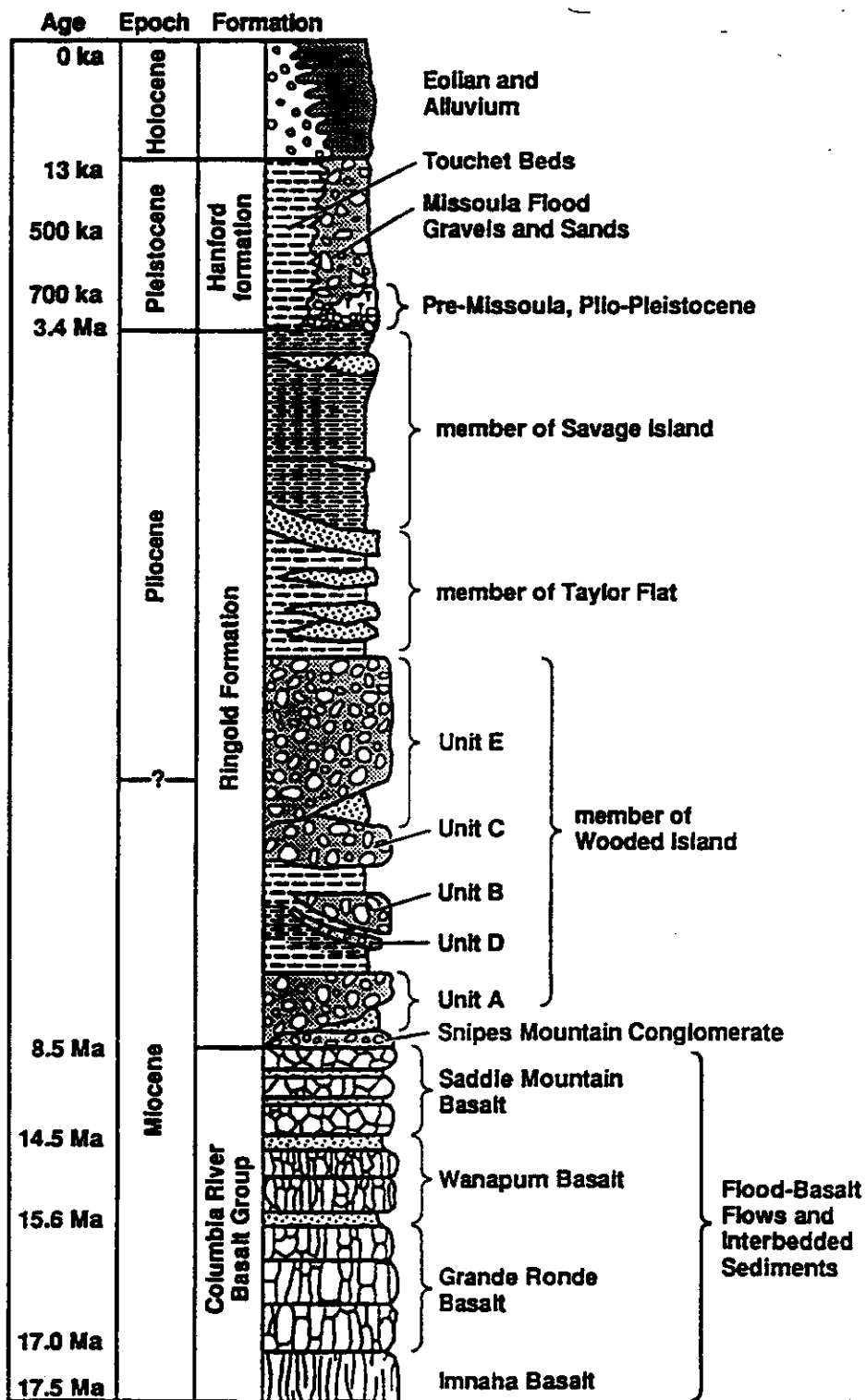


Figure 3-2. General Stratigraphy of the Hanford Site



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Figure 3-3. Geologic Cross Section Through the Hanford Site

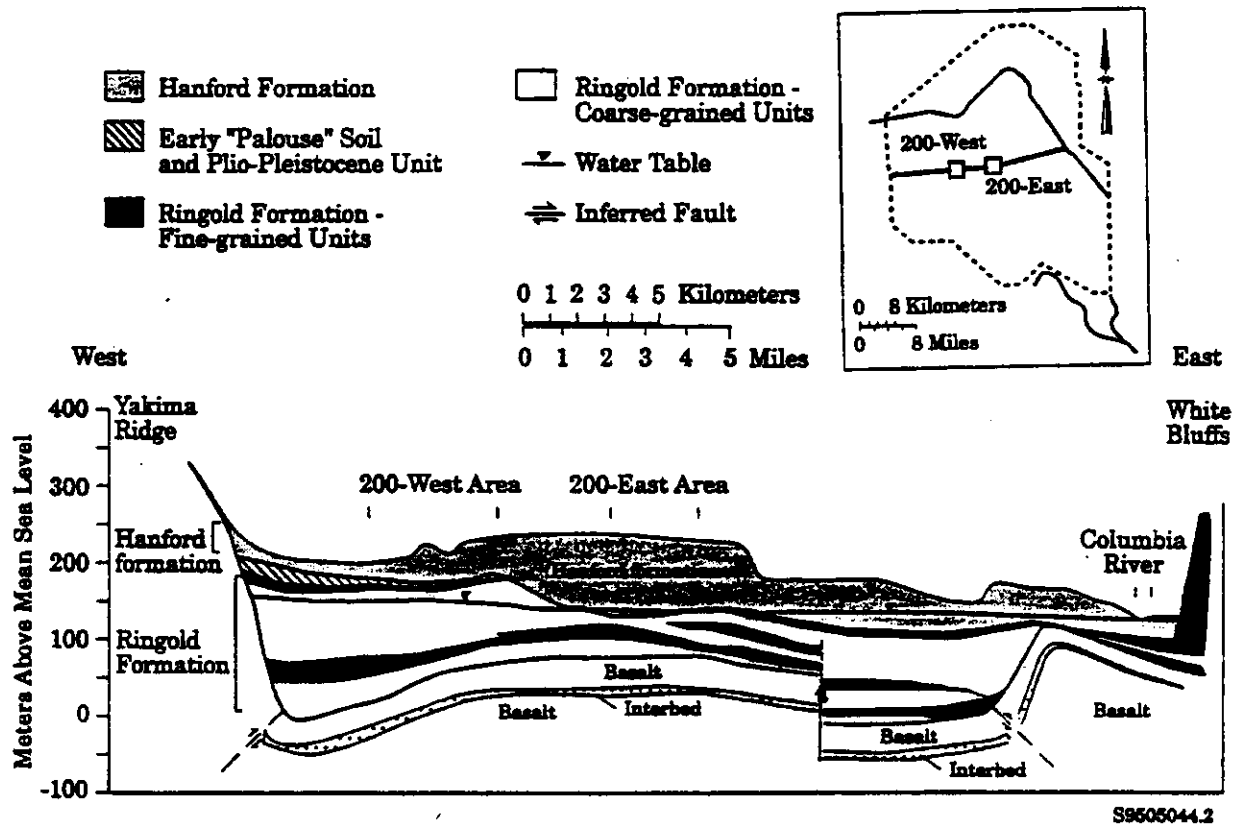
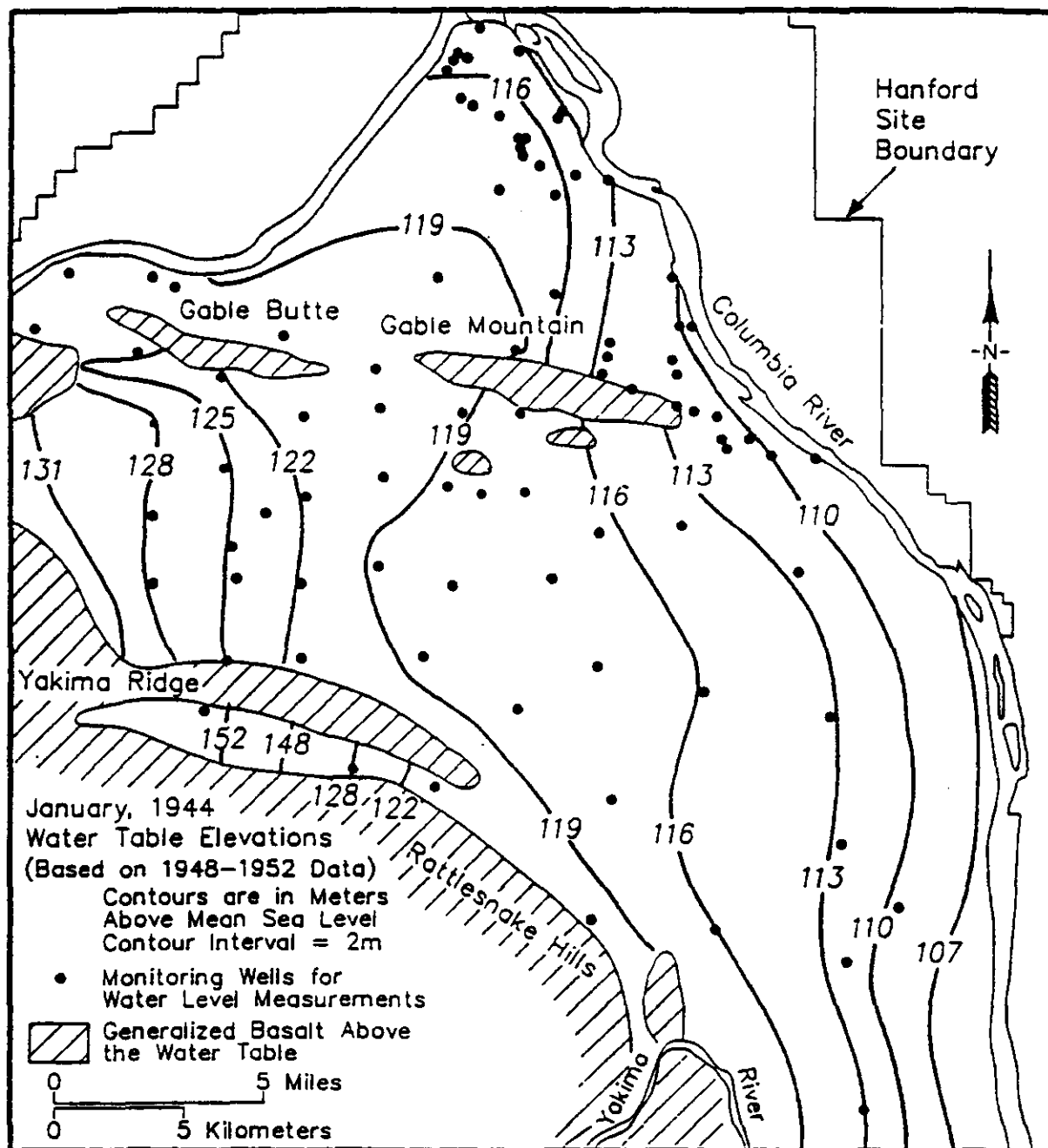
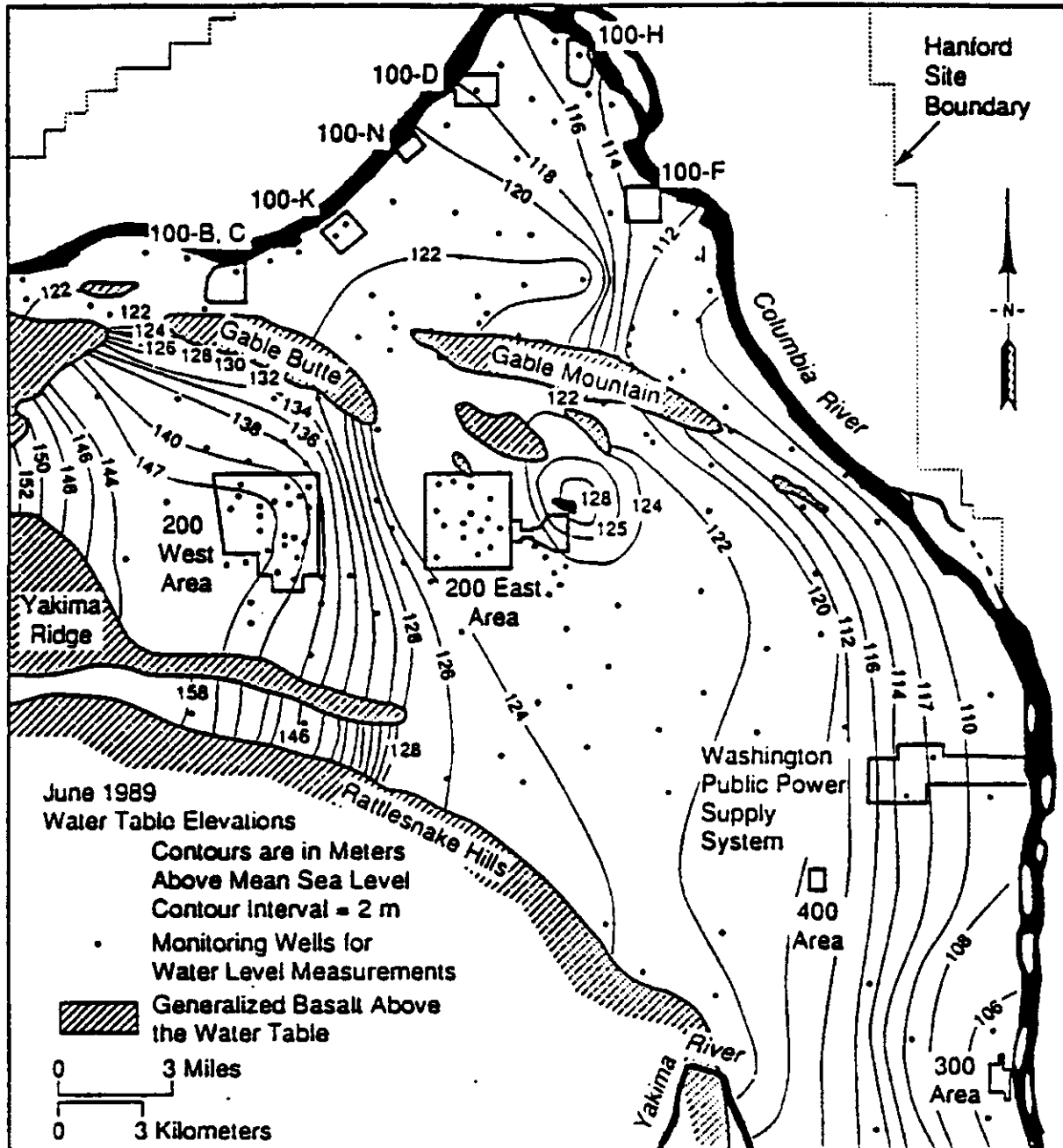


Figure 3-4. Hindcast Water Table Map of the Hanford Site, January 1944



GEOSCI\062191-A

Figure 3-5. Hanford Site Water Table Map, June 1989



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Figure 3-6. Hanford Site Water Table Map, June 1995

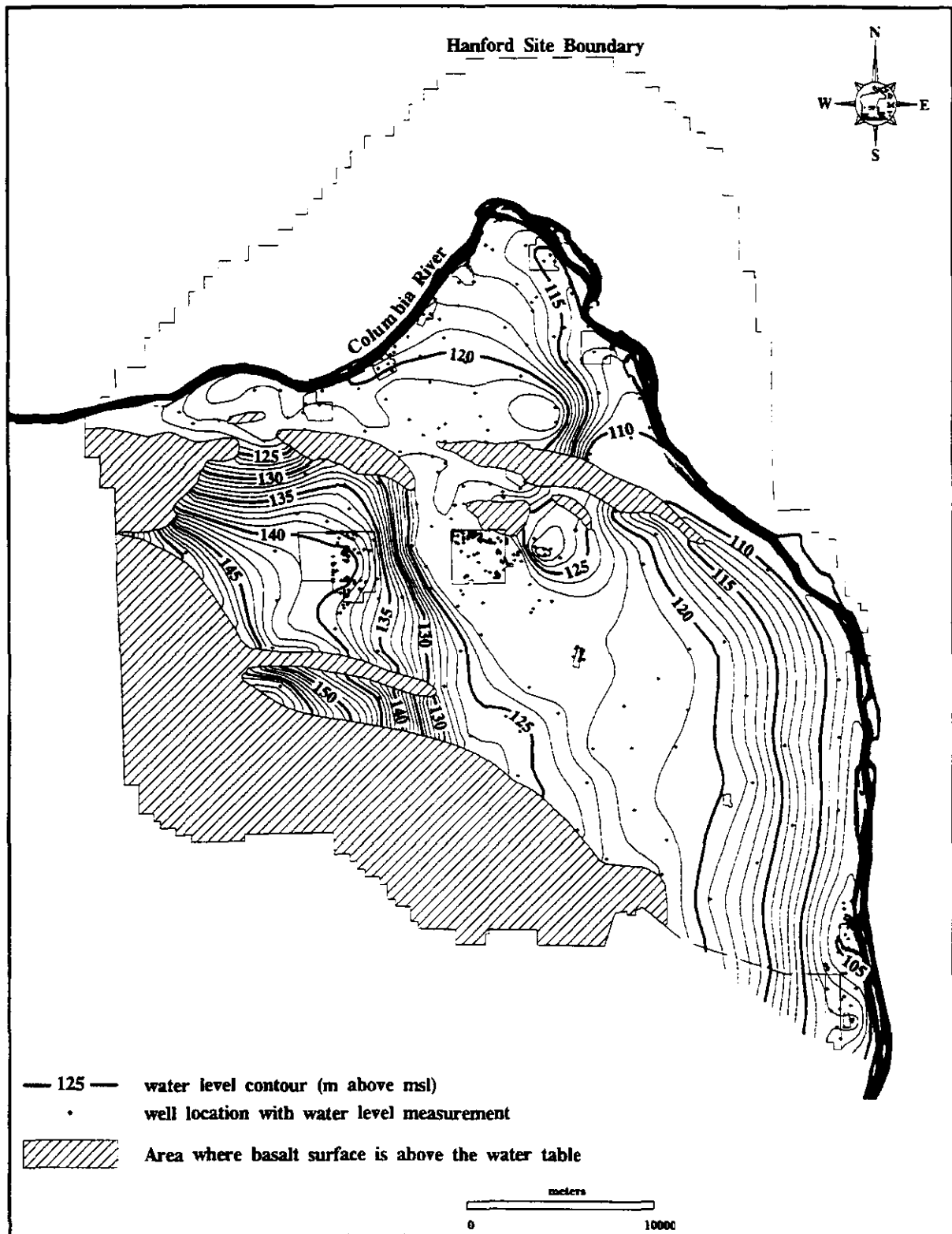


Figure 3-7. Tritium Concentrations in the Hanford Site Unconfined Aquifer, 1989

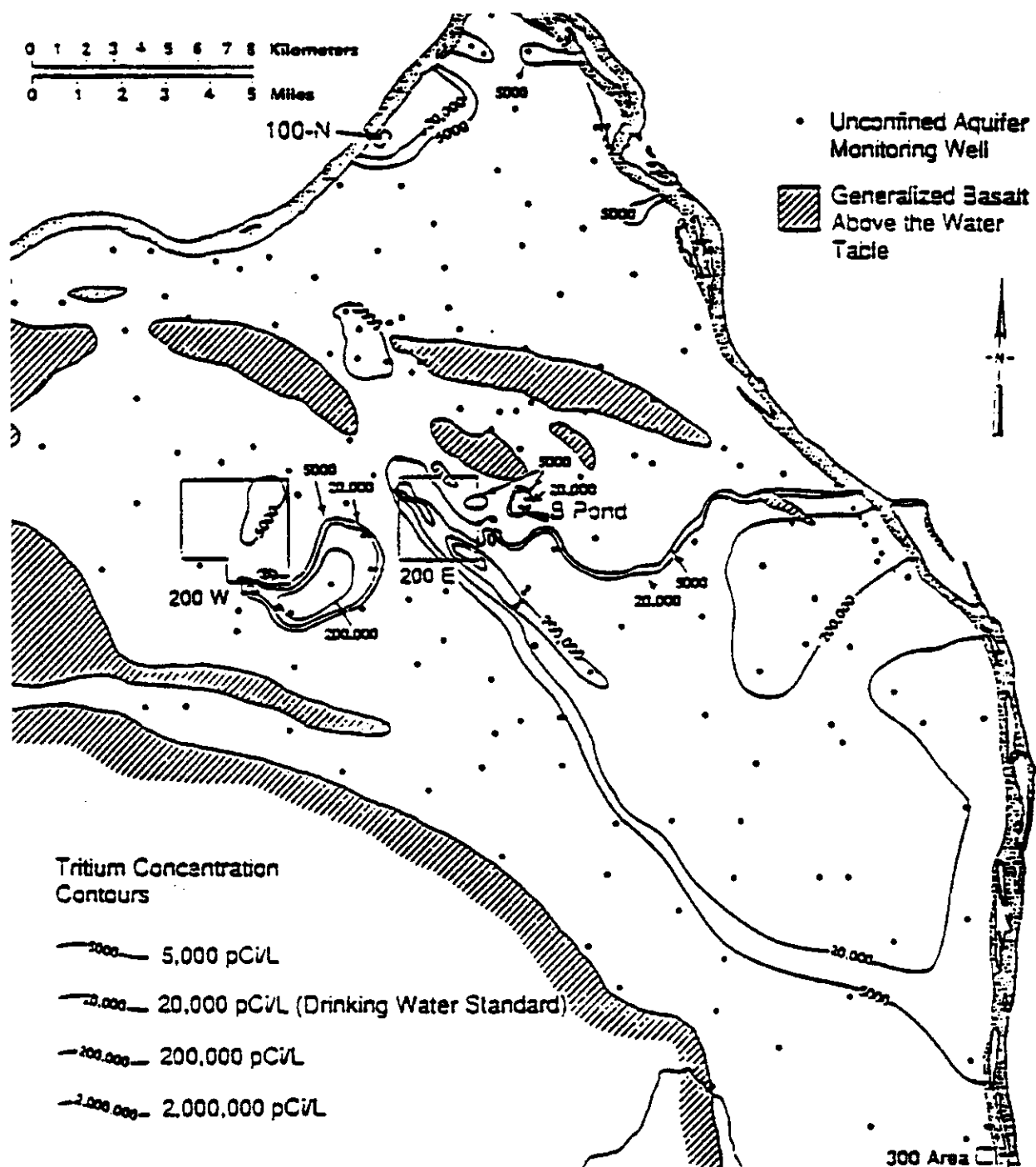
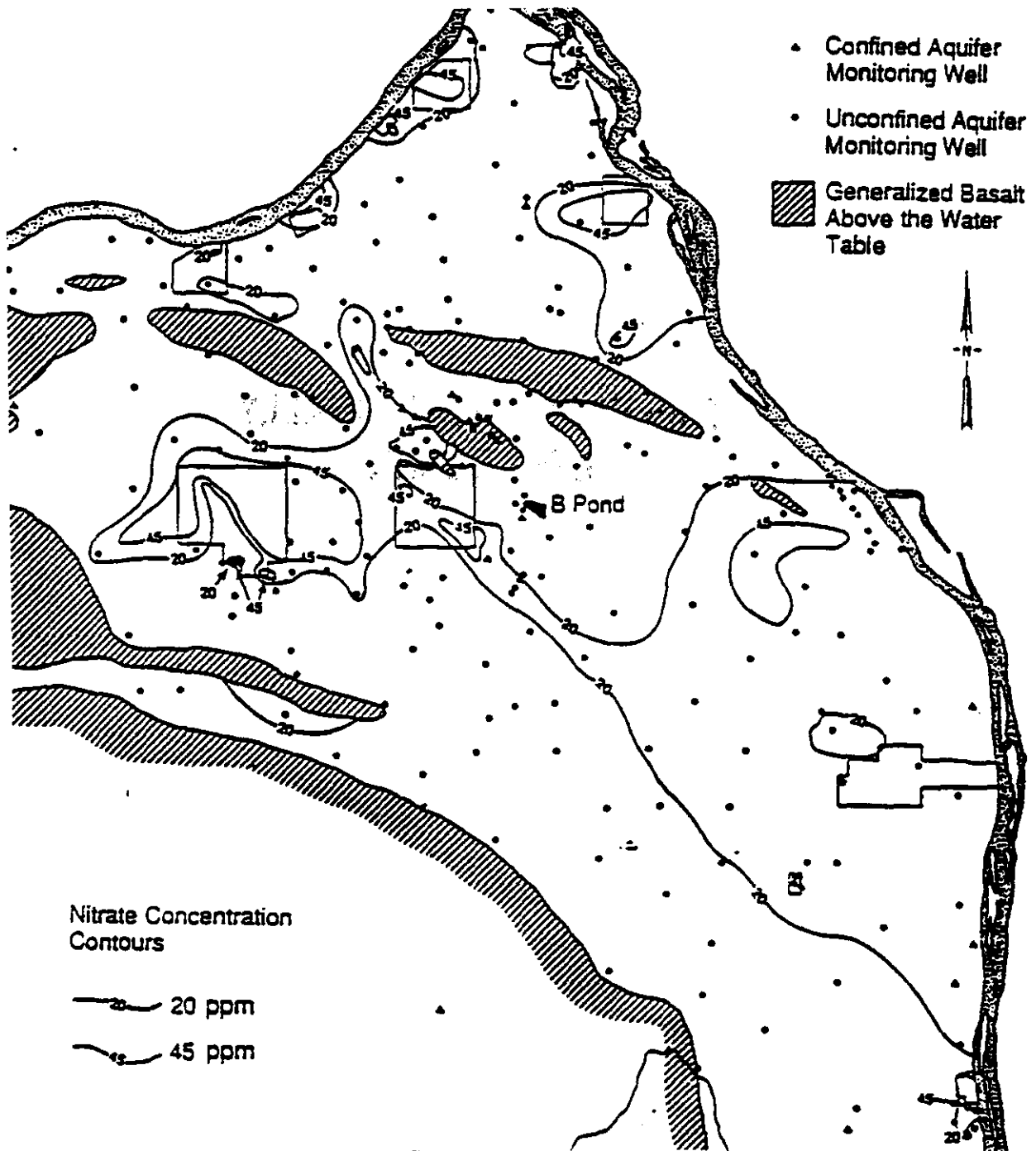


Figure 3-8. Nitrate Concentrations in the Hanford Site Unconfined Aquifer, 1989



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4.0 SELECTION AND SCREENING OF BACKGROUND WELLS AND COLLECTION OF NEW DATA

A large amount of groundwater data has been gathered throughout the history of Hanford Site operations. Most of this data has been collected to monitor for the presence of contamination in the groundwater, but some of the groundwater wells have been drilled and sampled for the purpose of collecting hydrologic data and establishing concentrations upgradient of the Hanford Site. A previous report of groundwater compositions (DOE-RL 1992) examined groundwater upgradient of the Hanford Site and also partially validated the conceptual model from experimental data. Results from that study indicated that additional data were needed to thoroughly characterize groundwater background by collecting and evaluating data from the entire unconfined aquifer. This new data should include all analytes that may be of concern for environmental remediation.

To gather compositional data that are representative of groundwater background at the Hanford Site, candidate wells were identified and then screened to determine their suitability for use in determining background concentrations. The well selection and screening process is discussed in Section 4.1. Data from the screened wells were then used to select a suite of candidate wells that would be sampled for the purpose of supplying background compositional information not available in the historical data set. The methods used to collect and analyze new groundwater data are presented in Section 4.2.

4.1 WELL SCREENING

The screening was conducted in several steps. First, a list of candidate background wells was chosen for initial screening, which consisted of applying several objective criteria to arrive at a list of potential background wells. The second step was to examine the list of wells produced from the initial screening, with respect to their proximity to known areas of groundwater contamination, and to eliminate wells suspected of being contaminated from Hanford Site sources. The third step was performed on data collected specifically for determining background. These data were closely examined for the presence of outliers that may be considered nonrepresentative, and the suspect data were censored from the final data set.

4.1.1 Initial Screening

For the initial screening, a suite of 74 wells from across the Hanford Site was chosen. These initial wells, identified by personnel who are familiar with the Hanford Site groundwater well network, were those that have the potential to represent background conditions in the upper unconfined aquifer. The goal of this selection process was to broaden the geographic coverage of groundwater wells from the previous study (DOE-RL 1992) to obtain a more representative set of groundwater background data. This initial screening was carried out in 1994.

All Hanford Site unconfined aquifer groundwater monitoring wells were evaluated as potential candidates. Wells within or proximal to known contaminant sites or plumes (e.g., within or near the tritium or nitrate plumes) were eliminated from the candidate well list. Hanford Site contractors and regulatory agencies were consulted and requested to identify wells that, in their judgment, were potentially free of contaminants. The set of wells resulting from this effort is listed in Table 4-1. Data from this set of wells were screened for detection of halogenated hydrocarbons; wells with groundwater containing halogenated hydrocarbons were eliminated from further consideration.

A background data set was constructed by requesting data files from the Hanford Environmental Information System (HEIS) database from 1989 through February 1993. This data included all chemical and radiological information for wells initially considered for inclusion in the background data set. Acquisition of data from the HEIS database ensured that data were constrained to conform to the quality control (QC) and quality assurance (QA) requirements of data entered in HEIS and included HEIS data qualifiers.

For the initial screening process based on the historical data, a target set of analytes was developed after consultation with Westinghouse Hanford Company (WHC) and Pacific Northwest National Laboratory (PNNL) geochemists and radiochemists and by referencing Hanford Site environmental reports. These target analytes, shown in Table 4-1, were determined to be those most likely to reflect concentration variations in response to contamination events or plumes. No *a priori* decision or definition of contamination was made.

For each analyte, histograms of concentrations over time were prepared and examined for each well to identify any evidence of contamination. Each well was graded by evaluating well concentrations against the threshold concentrations for the target analytes. These thresholds were based on data obtained from the preliminary background determination (DOE-RL 1992). The thresholds were then revised during the course of the screening effort to approximate the grand average of analyte concentrations, plus two standard deviations of the background population for data from acceptable wells. The threshold values are included in Table 4-1.

Following are the criteria used to grade the wells during the initial screening:

- Grade 1: No evidence of contamination over the time represented by sample data.
 - 1a: Wells recommended by the Washington Department of Health as representing groundwater background.
 - 1b: Other wells with indicator analyte levels at or below the screening criteria.
- Grade 2: No evidence of contamination within the previous five years, defined as subsequent to January 1, 1989.
 - 2a: Grade 2 wells with only one exceedance for a single analyte (i.e., a possible anomalous exceedance).

- Grade 3: No evidence of contamination, but data consistently below detection limits reported in the database (i.e., data were flagged in the database as "below detection").
 - 3a: Grade 3 wells with exceedances suspected to be attributable to instrument or data entry error.
- Grade 4: Contaminated within the past five years with contamination defined as a trend in concentration that was significantly increasing, or the presence of a contaminant plume, where "plume" was defined as a significant increase and later decrease in concentration.

In addition, each well was graded for each analyte according to the presence of fewer than three reported results within the past five years (Grade a), and for the presence of data "spikes" within the data (Grade b). "Spikes" were defined as single results greater than twice adjacent (temporally proximal) results for the same analyte. Secondary grades were not used in screening or for data manipulation after screening.

Results of screening for each well and each analyte are presented in Table 4-1. Wells considered to be contaminated within the past five years for any indicator analyte were eliminated as representative of groundwater background.

The screening method described above has several merits:

- Only analytes considered to be sensitive indicators of contamination are used to screen candidate (well-specific) subsets of data.
- The method does not evaluate the presence or absence of data for any analyte. For example, if data for a single analyte are present from a particular well, the well may be represented in the background data set, so data inclusive of all analytes of interest are not required to be represented at each location included in the background estimation. (Analytes for which no data were available are indicated as null entries in Table 4-1.)
- No concentration-dependent definition of contamination is required. This is an advantage because no objective and unambiguous basis for defining concentration-dependent contamination is possible for naturally occurring analytes. Data with relatively high values do not, with this screening method, require subjective judgment regarding their source as contaminants.

This initial screening effort resulted in the removal of 27 wells from further consideration as representative background wells (Table 4-1). Data from the remaining 47 wells were subjected to a refined screening process that is described in the following section.

4.1.2 Refined Screening of Historical Data

The screening effort described in Section 4.1.1 was refined to produce a list of background wells used to evaluate sitewide background using the historical data. This was accomplished by

examining the distribution of individual analytes from wells that passed the initial screening and identifying outliers (i.e., data that do not conform to the pattern established by other observations) for several key analytes. The individual steps used to accomplish this follow:

- 1) Obtain data for each of the wells identified from the initial screening as background candidates. All data collected from 1989 through February 1997 (inclusive) for each well were retrieved from HEIS.
- 2) Graphically identify outliers for each analyte and compile a list of wells that had at least one outlier.
- 3) Evaluate the location of each well with respect to known contaminant plumes and groundwater mounds.
- 4) Eliminate the analyte for all samples for that well if there is any indication of Hanford Site-related contamination. This includes an evaluation of secular equilibrium within the decay chain of naturally occurring radionuclides, where the data are available.

Some judgment was used in step four to decide which analyte(s) to remove or if all data or a specific subset from the well should be screened out. For example, if a well was located in a nitrate plume but had no other outliers, then nitrate was removed from the data set, but the other analytes were retained for the purpose of calculating statistics to represent sitewide groundwater background. Chromium is another analyte that was selectively removed from the well data if no other outliers were identified. In some cases, all data associated with a well were removed from the data set; in other cases all data on radionuclides were removed if the well was located near a process facility or a surface discharge unit into which radioactive material was disposed.

Several wells were situated in or near areas where contamination by multiple analytes had been documented. Examples of these are wells that are near groundwater mounds (e.g., Gable Mountain Pond, U-Pond). Where wells were shown to be influenced by groundwater mounds, all of the data were typically removed from the data set. Data removal was done because the samples could have been enriched in contaminants from process effluent, or natural groundwater compositions may have been diluted by fresh water being flushed through the vadose zone to groundwater.

Results from this screening process are presented in Table 4-1. All data from eight wells were completely eliminated from the initially screened historical data set because they were either located near groundwater mounds in areas of contamination involving several constituents, or the wells did not represent groundwater from the upper portion of the unconfined aquifer. Several constituents were eliminated from wells because they contained outliers that were suspected to be related to contamination.

Throughout this screening process, every effort was made to ensure that the data were not influenced by either past or current Hanford Site sources of groundwater contamination.

Locations of the wells that passed both the initial and refined screening processes are shown on Figure 4-1.

4.2 NEW GROUNDWATER DATA

Evaluation of the historical data from HEIS and the data obtained for a previous report on groundwater background (DOE-RL 1992) revealed several inadequacies that preclude a thorough description of groundwater chemistry in the unconfined aquifer beneath the Hanford Site. Although the historical data are of good quality and are useful for evaluating background for some analytes, these data are deficient for two primary reasons:

1. Completeness: Data from many of the wells lack values for some of the contaminants of potential concern in the groundwater. For example, some wells may only have analyses for nitrate, gross alpha and beta, and tritium. Several wells have few data on metals, while many wells lack information on individual radionuclides.
2. Sensitivity: Detection limits for several metals and radionuclides in the historic data are consistently above actual groundwater background values. Although many of these detection limits are below concentrations associated with measurable risk, background concentrations for some analytes (e.g., arsenic) may be above health-based standards. If all of the historical background data for an analyte are reported to be at or below a detection limit that is above background, then the true concentration of the analyte is unknown and the risk associated with background cannot be quantified.

Based on these considerations, it was determined that new data should be collected specifically to evaluate groundwater background at the Hanford Site. The next section describes how the wells used to supplement the historic data were selected, sampled, and analyzed.

4.2.1 Selection of New Groundwater Wells

An initial set of wells were chosen for groundwater sampling based on the analysis of historical data (see Section 4.1). Examination of the location of these wells indicated gaps in the geographic coverage, so several other wells that were not included in the historical evaluation were added in an attempt to provide thorough spatial coverage of the Hanford Site. The majority of these additional wells are located around the 100 Area and in or near the 1100 and 300 Areas. Specific wells from these areas were chosen as potentially representing background by personnel familiar with the groundwater monitoring networks at the Hanford Site. Figure 4-2 is a map showing the locations of the wells that were sampled.

To evaluate the feasibility of resampling, the set of wells was further examined with respect to their physical condition. Wells that could be sampled with a minimum of reconditioning were given priority over wells that required extensive refurbishment.

4.2.2 Refurbishment and Sampling of Wells

Wells that rated high on the rating system described in Section 4.1.1 were given first priority for refurbishment and sampling. All of the wells that were given a grade of one and two were refurbished and sampled, as were some wells in the grade three group.

Each well was examined prior to sampling by a remotely operated down-hole camera to determine if the wells needed to be reconditioned before sampling. If reconditioning was necessary, the well casing and screen were cleaned with a brush to remove deposits, and any debris were removed using a sandpump/bailer. The well was then developed to reduce well effluent turbidity and/or increase aquifer communication. The well was pumped until the well effluent was less than or equal to 5 nephelometric turbidity units (NTUs). Well development involved surging, swabbing, bailing, and/or constant flow pumping. After the cleaning and development tasks were concluded, a final camera survey was performed to evaluate the condition of the restored well. When the internal integrity of the well had been restored, a submersible sampling pump was placed in the well.

Sampling was carried out in 1993 and 1994 by personnel from WHC and PNNL. To ensure that no well-related contaminants were collected before a well was sampled, groundwater was purged from the well until turbidity was no greater than 5 NTU. As many as eight water samples were collected for each well, consisting of filtered and unfiltered samples for metals, anions, radionuclides, and organics. Sample collection followed EPA SW-846 sample handling and documentation protocols (EPA 1986).

4.2.2.1 Nonradionuclides. Unfiltered and filtered (0.4 micron pore size) samples were collected for analysis of metals, anions, and organic analytes. Samples to be analyzed for cations were acidified with hydrochloric acid. Samples for anion analysis were unpreserved with the exception of sulfide, which was treated with zinc acetate and sodium hydroxide per EPA methods. Samples to be analyzed for ammonia were treated with sulfuric acid; sodium hydroxide was added to cyanide samples as a preservative.

Field measurements for analytes sensitive to storage or atmospheric exposure were taken at each well site during pumping. A flow-through cell (DS3 Data Sonde™, Hydrolab, Austin, Texas) was used to determine dissolved oxygen, pH, conductivity, temperature, and Eh at the ground surface. Groundwater was pumped through the cell by means of a length of tubing attached directly to the pump discharge pipe; the water did not interact with the atmosphere prior to analysis. The Sonde was calibrated with standard solutions and buffers for conductivity and pH. Calibration for oxygen was made using the atmosphere for oxygen, and quinhydrone buffer solutions were used for Eh calibration. After turbidity was determined to be below 5 NTU, flow was started through the cell and allowed to equilibrate at least 10 minutes. Readings were either stored in an automated data logger or recorded directly into a controlled laboratory record book.

4.2.2.2 Radionuclides. Filtered and unfiltered samples were obtained from each well for analysis of gross alpha, gross beta, tritium, and iodine-129. The aliquots for gross alpha and

gross beta determination were acidified with nitric acid; aliquots for tritium and iodine-129 analyses were not acidified.

Gamma-ray emitting radionuclides and plutonium-238, plutonium-239/240, americium-241, and strontium-90 were concentrated using the Battelle large volume water sampler (BLVWS). This collection device consists of a series of sorption beds that provide the capability to concentrate radioactive dissolved species from large volumes of water. Approximately 250 gal (950 L) of groundwater was pumped through a 0.4 μm pore-size prefilter and then through a series of ion-exchange resins. These resins concentrated cationic, anionic, and non-ion-exchangeable or neutral species from water.

4.2.3 Analysis of Samples From New Groundwater Wells

All filtered and unfiltered samples were analyzed for inorganic cation and anion constituents, various organic constituents, and radionuclides. Field measurements including temperature, pH, and total dissolved solids were also obtained. Several samples were analyzed for stable carbon, hydrogen, and oxygen isotopic ratios. All of the measurements (except stable isotope ratios and organics) were made by laboratories at PNNL. The following sections detail the analytical techniques used for these analyses.

4.2.3.1 Inorganic Analyses. Metals were analyzed on a Fisons PlasmaQuad™ Model PQIIS inductively coupled plasma mass spectrometer (ICP/MS). There was no sample preparation before analysis other than the acidification performed in the field. Analytes with concentrations above the range of this instrument (e.g., sodium) were analyzed by inductively coupled plasma atomic emission spectrometry (ICP/AES) using a Fisons Model 3410 instrument. Ion chromatography was used to analyze for anionic constituents, using a Dionex™ Model 2020i automated instrument. All of these analyses used laboratory QA/QC protocols performed to "Good Laboratory Practices," detailed in PNL-MA-70 and performed at Impact Level III. Analysis of stable isotopes were made at Washington State University.

4.2.3.2 Organic Analyses. Measurements of carbon (e.g., total organic carbon, total carbon) were made on a Dohrmann CD-80™ carbon analyzer at PNNL. Other organic analyses were performed by an outside laboratory using EPA standard methods.

4.2.3.3 Radionuclide Analyses. Analysis of gross alpha, gross beta, tritium, and iodine-129 were performed on aliquots of the well water. For gross alpha and beta measurements, 200 mL of water was dried on a counting planchet and counted for 1,000 minutes. The alpha detector was calibrated to plutonium-239, and the detection limit was approximately 0.5 pCi/L. A detection limit of approximately 0.3 pCi/L was realized for total beta, with the detector calibrated using strontium-90/yttrium-90.

Tritium was measured by distilling a groundwater sample in a Lachat tube apparatus, and counting a 2 mL sample of distillate for 200 minutes by liquid scintillation. Based on the instrument background count rate, the detector efficiency, and the sample size, the method detection limit for tritium varied from 200 to 310 pCi/L.

Iodine-129 was analyzed by spiking the groundwater sample with iodine-125; the sample was then dried and burned with the off-gases captured on a charcoal trap. This sample was concentrated, purified, and loaded onto a filament that was analyzed in a negative ion thermal emission mass spectrometer. Detection limits for iodine-129 were on the order of a few aCi/L (1 aCi/L = 1×10^{-6} pCi/L)

Measurements for the gamma-ray-emitting radioisotopes were made directly from the resin beds removed from the BLVWS. These radioisotopes included the following: potassium-40, cobalt-60, ruthenium-106, antimony-125, cesium-137, europium-152, europium-154, radium-226, radium-228 (from the daughter actinium-228), uranium-235, and uranium-238. The resin was dried and aliquots were transferred to 500 mL Marinelli beakers for gamma-ray counting by germanium detectors.

After the resin beds were analyzed by gamma spectroscopy, the beds were leached and prepared for analysis of strontium, plutonium, and americium radioisotopes. For plutonium and americium, the leachate was dried and ashed for approximately 24 hours to oxidize the organic residue from the resin, and the sample was dissolved in aqua regia. After filtering and precipitation, the samples were counted by alpha energy analysis. Strontium-90 was analyzed by allowing ingrowth of yttrium-90 then using Cherenkov counting to measure yttrium-90, from which strontium-90 activity was calculated.

4.2.4 Screening Data from New Groundwater Wells

The new data were screened in the same manner as the historic data (Section 4.1.2); analytes that were demonstrated or suspected to be unrepresentative of background were removed from the data set. Several wells that were not included in the historic data were sampled and analyzed as discussed in Section 4.2.1. These wells were evaluated according to the same procedure used for the historic data. Results of this screening process are presented in Table 4-1.

4.3 SUMMARY OF WELL SELECTION AND COLLECTION OF NEW DATA

The network of wells used for evaluating sitewide groundwater background were chosen by personnel familiar with Hanford Site groundwater chemistry. The intent of the selection process was to obtain data from samples that are representative of background conditions. Providing good geographic coverage and avoiding areas of known contamination were the primary requirements for the resulting set of wells. Historical data from the final set of wells were obtained from HEIS and subjected to a screening process to filter out any samples that showed a possibility of contamination.

Many of the wells selected from the screening process were chosen to be resampled, which consisted of refurbishing wells to prepare for sampling to ensure that contaminants were not present when new samples were taken. Filtered and unfiltered samples were obtained according to established protocols. A large volume water sampler was used to concentrate groundwater for analyses of radionuclides. Most groundwater analyses were conducted in laboratories at PNNL

using techniques that could produce detection limits lower than those associated with routine analyses.

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Figure 4-1. Locations of Historical Wells Used for Groundwater Background

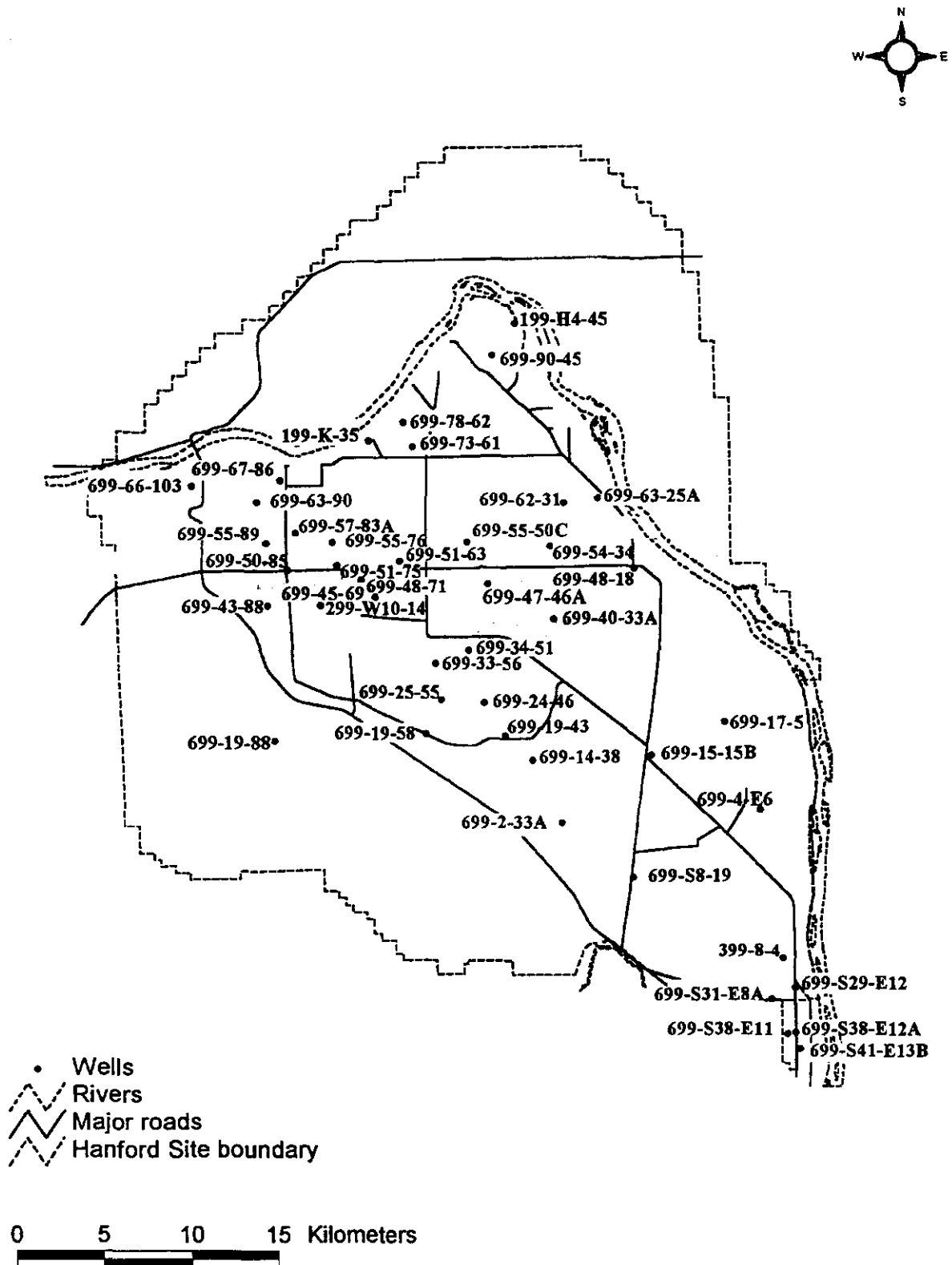
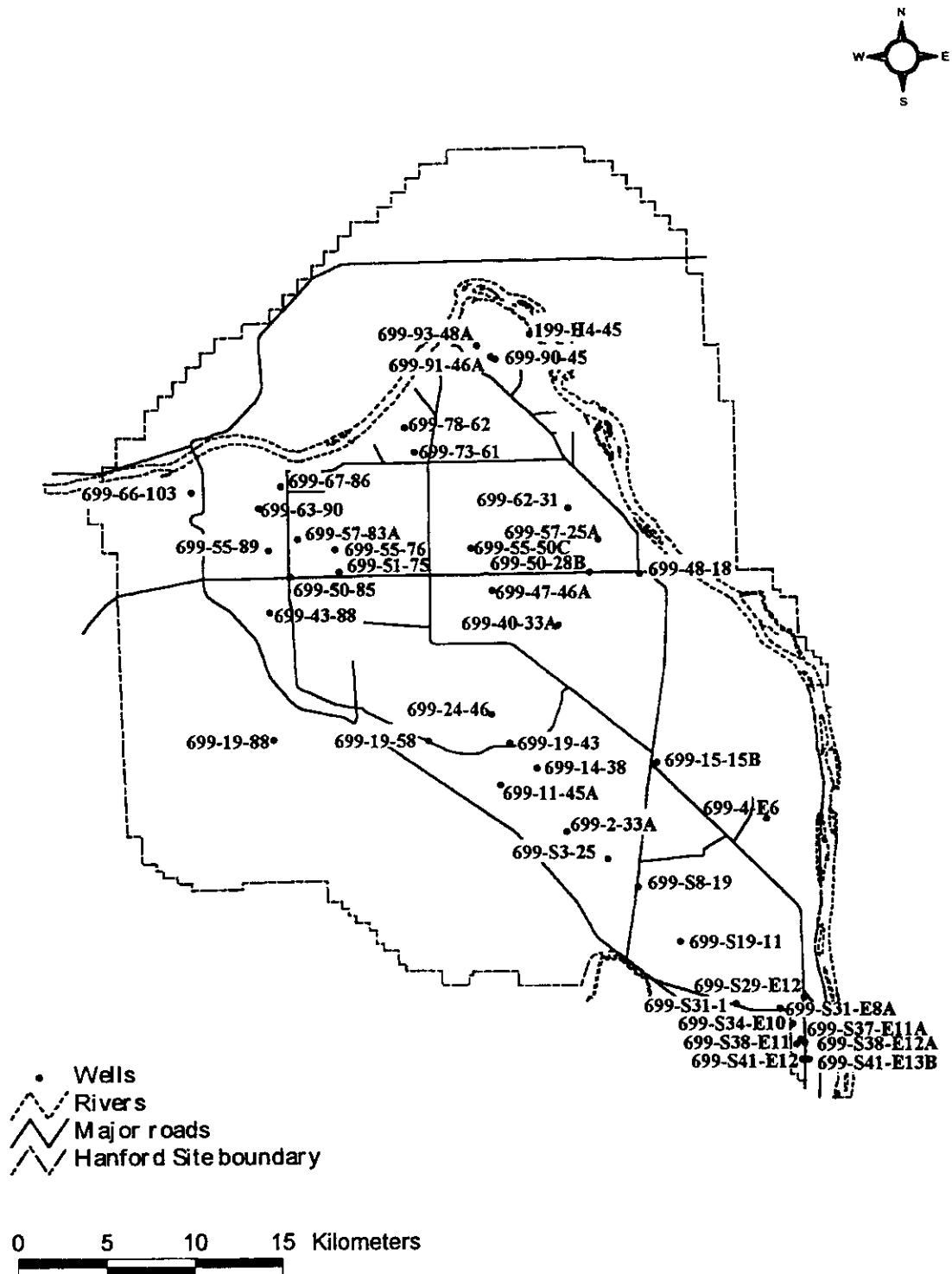


Figure 4-2. Locations of New Wells Used for Groundwater Background

06-24-96/kap/hgis

Table 4-1. List of Wells Evaluated in Initial Screening (Page 1 of 3)

Well	Co-60	Cs-137	NO3	Tc-99	Alpha	Beta	As	Cr	SO4	Selection	Remove from Historical Data	Remove from New Data
Threshold:	19	8.3	1808	0.4	6	20	10	30	53490			
199-H4-45	3	3	1B	1	3	4	4	4	4	Out	Remove all	Remove all
199-K-35	3	3	1B	1	3	1	1A	1	1B	In	Remove all radionuclides (except K-40), Cr	NA
299-W10-14	1	3	1	3	1	1	3	3	1	In	Deep well, remove all	NA
299-W15-17	3	1	1	1	1	1	3	3	1	In	Deep well, remove all	NA
299-W18-22	1	1	1	3	1	1	3	3	1	In	Deep well, remove all	NA
299-W6-3	3	3	1	4	1	4	3	3	4	Out	Remove all	NA
299-W6-6	3	1	1	1	1	1	3	3	4	Out	Remove all	NA
399-8-4	3A	3	1	1	3	3A	1		1B	In	Remove all radionuclides, uranium	NA
699-11-45A						3					No data; evaluate new data independently	Retain all
699-14-38			1	1B	1	1B		3	1	In	Remove Tc-99, I-129, H-3	Remove I-129, H-3
699-15-15B	3	1	1	1B	1	3	3B	3B	1B	In	Remove Tc-99	
699-17-5	3	1	4	1A	1	2		3B	1A	Out	Remove all	NA
699-19-43			1	1	1	1B	3B	3	1	In	Retain all	Retain all
699-19-58			3	1B	1	1A				In	Remove Tc-99	
699-19-88			3	1B	1	2	3B	3B	4	Out	Remove all	Remove all
699-2-33A			1	1B	1	3	3B	3B	1	In	Remove all radionuclides	Remove all radionuclides
699-24-46			4	1B	1	3		3	1	Out	Remove Tc-99, NO3, H-3	Remove NO3, H-3
699-25-55			1	1B	1	1B	3B	3B	1B	In	Remove Tc-99, NO3, H-3	NA
699-33-56	3	2	4	1	3	3	3	3	1	Out	Remove all	NA
699-34-51	3	2	4	1A	3	2	3B	3B	4	Out	Remove all	NA
699-4-E6			1						1B	In	Remove I-129, H-3	
699-40-33A											NA	Remove all
699-43-88			1		2	2	3	3	1B	In	Retain all	Retain all
699-45-69A	3	3	1	1B	1	2	3	3	4	Out	Remove all	NA
699-47-46A	3	3	1	1B	1	3	3	3	1	In	Remove Tc-99, H-3, SO4, I-129	Remove H-3, SO4
699-48-18	1B	1B	4	1B	1	1	3B	3	4	Out	Remove all	Remove all
699-48-71	1B	3B	1	1B	1	3	3B	3	1	In	Remove all radionuclides (except K-40), NO3	NA
699-50-28B											NA	Remove I-129
699-50-85			1	1B	1	3	3	3	1	In	Remove all radionuclides (except K-40), NO3	Remove all radionuclides (except K-40), NO3
699-51-63			1	1		1A			1	In	Remove all radionuclides (except K-40), NO3	NA
699-51-75			1	3B	2	1A	3	3,2	1,2	In	Remove all radionuclides, Cr	Remove all radionuclides, Cr
699-54-34			1	1B	1	1	3	3	3,1	In	Retain all	NA
699-55-50C	2	3	3A	3A	1	3	3B	3	1	In	Remove all radionuclides	Remove all radionuclides
699-55-76	3B		1	1B	3	3	3B	3	1A	In	Remove SO4, Cl, Cu	Remove SO4, Cl

Table 4-1. List of Wells Evaluated in Initial Screening (Page 2 of 3)

Well	Co-60	Cs-137	NO3	Tc-99	Alpha	Beta	As	Cr	SO4	Selection	Remove from Historical Data	Remove from New Data
699-55-89	1	3	1A	1B	1		3	3	1	In	Remove all radionuclides	Remove all radionuclides
699-57-25A											NA	I-129
699-57-83A			1			1B				In	Retain all	Retain all
699-62-31			1	1B					1	In	Remove all radionuclides, NO3	Remove all radionuclides, NO3
699-63-25A	1B	1B	1	3B	1	3		3	1	In	Remove all radionuclides, SO4	NA
699-63-90	1	3	1	1	1	3	1	1	1A	In	Remove all radionuclides (except K-40), NO3	Remove all radionuclides (except K-40), NO3
699-66-103	3	3	3A		3	1				In	Retain all	Retain all
699-67-62	3	3	1	1	1					In	Retain all	NA
699-67-86	1B	3B	1	4	1	2	1	4	1	Out	Remove all radionuclides (except K-40), Cr, Pb	Remove all radionuclides (except K-40), Cr, Pb
699-73-61	3	3	1	3	1A	1	1	1	1	In	Remove all	Remove all
699-78-62	3		1		1	2	3	4	1	Out	Remove all	Remove all
699-90-45			1	1A	1	1A	3B	3	1	In	Remove all radionuclides	Remove all radionuclides, As, Cr
699-91-46											NA	As, Cr
699-93-48											NA	Remove all radionuclides, As, Cr
699-S12-3	1A	2	2	3B	1A	2	3B	3	1A	In	Remove all	NA
699-S14-20A	3	3	1	3B	3B	1A	3B	3B	1B	In	Retain all	NA
699-S19-11	1	1	1	3		1	3	3	1	In	Remove all radionuclides, SO4	Remove all radionuclides, SO4
699-S24-19			3			1B				In	Retain all	NA
699-S27-E14	1	1	1A	1	3	4	1	3	4	Out	Remove all	NA
699-S29-E12	1B	3B	1A	1A	3A	3	2,1	3	1	In	Remove all radionuclides, NO3, SO4	Remove all radionuclides, NO3, SO4
699-S3-25			3	3B	1	1		3B	4	Out	Remove all	Remove all
699-S30-E10A	3B	1B	1	4		4	4	3	1	Out	Remove all	NA
699-S30-E10B	1B	1B	1	1		1	3	3	1	In	Remove all	NA
699-S30-E15A	3	3	4	4	3A	1A	1,3	3	1A	Out	Remove all	NA
699-S31-1	3B		1		3	4	3B	1	1	Out	Retain all	Retain all
699-S31-E8											NA	Remove I-129, NO3, Cl, Ni
699-S31-E10A	1B	1B	1	1	1	4	4	3	1	Out	Remove all	NA
699-S31-E10B	1B	3B	1	1	1	4	4	3	1	Out	Remove all	NA
699-S31-E10C	3B	3B	1	1	1	1	1	3	1	In	Remove all	NA
699-S31-E10D	1B	1B	1	1	1	4	1	3	1	Out	Remove all	NA
699-S31-E13			1		1	1A	1	3	1	In	Remove NO3	NA
699-S31-E13B					4					Out	Remove NO3	NA
699-S32-E13A			1		1	1	1	3	1	In	Remove all	NA
699-S32-E8	3B	3B	3B	1	1	1	4	3	4	Out	Remove all	NA
699-S34-E10	3B	3B	1	1	1	1	1	3	4	Out	Remove all	Remove all

Table 4-1. List of Wells Evaluated in Initial Screening (Page 3 of 3)

Well	Co-60	Cs-137	NO3	Tc-99	Alpha	Beta	As	Cr	SO4	Selection	Remove from Historical Data	Remove from New Data
699-S37-E11											NA	Retain all
699-S37-E14	1	3	1A	1A	1	1	3	3	1A	In	Remove all	NA
699-S38-E11			1		1	1	1	3	1	In	Remove all	Remove all
699-S38-E12A			1		1	1	1	3	1	In	Retain all	Retain all
699-S38-E12B			1		4	1	4	3	1	Out	Retain all	NA
699-S40-E14			1A		3	1	3	3	1	In	Retain all	NA
699-S41-E12	3B	1B	1B		1A	1	1A	3	1A	In	Remove all	Remove all
699-S41-E13A			1	1B	3	1	3	3	1	In	Remove all, contains organic halides	NA
699-S41-E13B	3B	1B	1	1B		1	1A	3	1	In	Remove all, contains organic halides	Remove all, contains organic halides
699-S41-E13C	1B	3B	4	1	1	1	1A	4	1	Out	Remove all	NA
699-S43-E12			1		4	4	3	3	1	Out	Remove all	NA
699-S8-19			4	3B	1	2	3B	3	4	Out	Retain all	Retain all

Legend for evaluation criteria:

1. No evidence of contamination over the time represented by sample data.
2. No evidence of contamination within the previous five years, defined as subsequent to January 1, 1989, or only one exceedance for a single analyte (i.e., a possible anomalous exceedance).
3. No evidence of contamination, but data consistently below detection limits reported in the database (i.e., data were flagged in the data base as "below detection"), or exceedances suspected to be attributable to instrument or data entry error.
4. Contaminated within the past five years with contamination defined as a trend in concentration that was significantly increasing or the presence of a contaminant plume, where "plume" was defined as a significant increase and later decrease in concentration.

5.0 DATA SUMMARY AND EVALUATION

The data compiled and collected for this study are described and evaluated in this chapter. The historical data are presented and evaluated in Section 5.1, and the new data collected specifically to provide additional information on background compositions are evaluated in Section 5.2. Comparison of these two sets of data is presented Section 5.3. A summary of the combined Hanford Site background data set is contained in Section 5.4.

5.1 SUMMARY OF HISTORICAL DATA

The selected, screened historical data described in Section 4.1 comprise a database consisting of 41 wells whose locations are presented in Figure 4-1. The data associated with these wells contain a total of 5,562 data for 71 constituents. The data are not tabulated in this report, as they are available in the HEIS database, and the screened constituents are detailed in Table 4-1. This section presents a statistical summary of the historical data.

The first step in the analysis was to evaluate data reported as being less than or equal to the detection limit. Detection limit values are required by the MTCA (WAC 173-340) to be assigned a value of one half of the detection limit, regardless of the percentage of detection limit values associated with an analyte. Other methods have been developed to evaluate these left-censored data with more statistical rigor (EPA 1989c; Gilbert 1987), but statistics reported here will follow the MTCA guidance. This approach introduces a bias into the data that cannot be quantified unless additional information is known about the distribution of the data below the detection limit. A summary of detection limits associated with the data is contained in Table 5-1.

The second step toward completing a statistical summary of the data was to decay the radionuclides with half-lives of less than 1,000 years to June 1, 1997. The third step was to average all values in a well for each constituent. Several of the wells are on a quarterly sampling schedule, so over 20 values for each analyte may be reported over the seven-year period. No adjustments were made for seasonal variations in groundwater chemistry, because evidence strongly indicates that these variations are not discernable beneath the Hanford Site away from the rivers (Johnson et al. 1994).

The data resulting from the above adjustments were then statistically summarized by computing the mean and standard deviation along with the geometric mean and geometric standard deviation, minimum and maximum values, and the 90th and 95th percentiles. These data are presented in Table 5-1. All of the statistics were computed on a lognormal distribution because it was determined during the screening process while evaluating outliers that most of the data follow a lognormal rather than a normal distribution. A discussion of the use of graphical plots to show the shape of the distribution for various analytes is presented in Section 5.3.

The historic data were collected over the course of seven years and analyzed in different laboratories, which resulted in a data set with varying constituents and detection limits both within and between wells. As an example, there are six constituents reported for Well 699-62-31, while Well 699-63-90 has 65 constituents reported in HEIS. Detection limits for some analytes also vary widely; phosphate ranges from 72 to 2,000 $\mu\text{g/L}$, and selenium ranges from less than 1 to 19 $\mu\text{g/L}$. Detection limits for radionuclides are generally in the one to 100 pCi/L range.

5.2 SUMMARY OF NEW DATA

The data collected specifically for determination of Hanford Sitewide groundwater background were screened according to the process detailed in Section 4.2, and the detection limit data were adjusted using the procedure described in Section 5.1. The new data set contains 4,102 data collected for 71 analytes from 32 wells. Statistical summaries of the chemical and radionuclide data are presented in Table 5-2. Most of the wells were sampled and analyzed only once, but wells that had more than one analyses per analyte were averaged, and these averages were pooled with the other data to compute the statistics. As with the historical data, the new data follow a lognormal distribution, and statistics were calculated accordingly. The new samples were also analyzed for volatile and semi-volatile organic constituents. All of these results were less than detection limits. Table 5-3 contains the list of organics analyzed.

These new data have considerably lower detection limits for most analytes than those of the historical data. This is especially true for the radionuclides, which are routinely three orders of magnitude below detection limits for the historical data, owing to the collection method employed (Sections 4.2.2.2 and 4.2.3.3). Detection limits for several of the environmentally important metals (e.g., arsenic, chromium) are a factor of two or more below those associated with the historical data.

5.3 COMPARISON OF HISTORICAL AND NEW DATA

It is clear from the previous discussion that the historical and new data sets are different. The historical data were collected to monitor groundwater compositions, occasionally in connection with a specific unit. Because most of the wells were not sampled and analyzed for the specific purpose of determining background, these data may lack analytes important in the consideration of background composition. The new data were collected and screened for the purpose of defining background conditions in the upper unconfined aquifer, and, as such, constitute an internally consistent data set containing all of the analytes of interest for evaluation of background. The new data lack temporal coverage, however, as most wells were sampled only once.

Detection limits are also substantially different for some of the analytes, especially metals. The ICP/MS analytical technique used on the new samples is capable of lower detection limits than the conventional ICP/AES technique routinely employed for environmental samples. Detection

limits for the radionuclides are also substantially lower than those achieved in routine analysis because of the concentration and analysis techniques employed (Section 4.2.2.2). A comparison of maximum detections limits reported for the old and new data can be made from the data contained in Tables 5-1 and 5-2.

It would be conceptually appealing to combine the two data sets discussed in this chapter to create one large, comprehensive set of data from which the range of background compositions can be described. To do this, a demonstration of the independence of the data would be required. Given that many of the samples from both data sets were collected from the same wells during the same time periods, an assumption of independence must be ruled out, so statistics derived from the data must use only one of the data sets for each analyte.

The two different data sets can be qualitatively compared to give an indication of their similarity. Graphical comparisons of some analytes from each data set are presented in Figures 5-1 through 5-5. These are cumulative distribution plots, which are also effective for determining the distribution of the data. As shown in the figures, most of the historic and new data follow a lognormal distribution. In these figures, detection limit values were generally suspended for analytes with a high number of detection limit data to properly compare the distributions. The number of data and suspensions can be determined from the numbers labeled "n/s" in the lower right of the plots. The numbers labeled " r^2 " are parameters that indicate the fit of the data to a lognormal distribution ($r^2=1$ is a perfect fit). Data from filtered samples were used for comparison of metals; both filtered and unfiltered data were used for the comparison of anions.

Most of the plots show that the distributions of the data are similar. The main exception is chromium, which was plotted with the detection limits included because they are so different for the historical and new data (10 to 20 ppb vs. 1 ppb, respectively) and have a profound effect on the final statistics.

5.4 SUMMARY OF DATA

The data from samples collected from 1989 through 1997 were screened according to a procedure designed to eliminate contaminated samples from the data set. Evaluation revealed that useful background information could be obtained from this screened data, but for many analytes data were either lacking or were of little use because of the high detection limits.

The new data were collected and analyzed for the sole purpose of establishing the range of background compositions in the upper portion of the unconfined aquifer. To accomplish this, filtered and unfiltered samples were obtained and analyzed for metals and anions. Analytical methods were selected based upon their ability to achieve lower detection limits than commonly realized employing conventional analytical techniques. Samples for radionuclides were obtained from a collection device that concentrated soluble species, allowing much lower detection limits than could be obtained from conventional samples.

The new data set holds several advantages over the old data set for the purpose of establishing groundwater background. These advantages include the following:

- Lower detection limits for most metals and radionuclides
- An internally consistent data set resulting from using the same laboratories and methods for all samples
- Rigorous control of well integrity and sampling techniques.

Graphical comparison of the two sets of data were made to evaluate the distribution of the data and similarities between the two sets. Graphical comparisons, using the cumulative distribution plot, illustrate the lognormal character of most of the analytes.

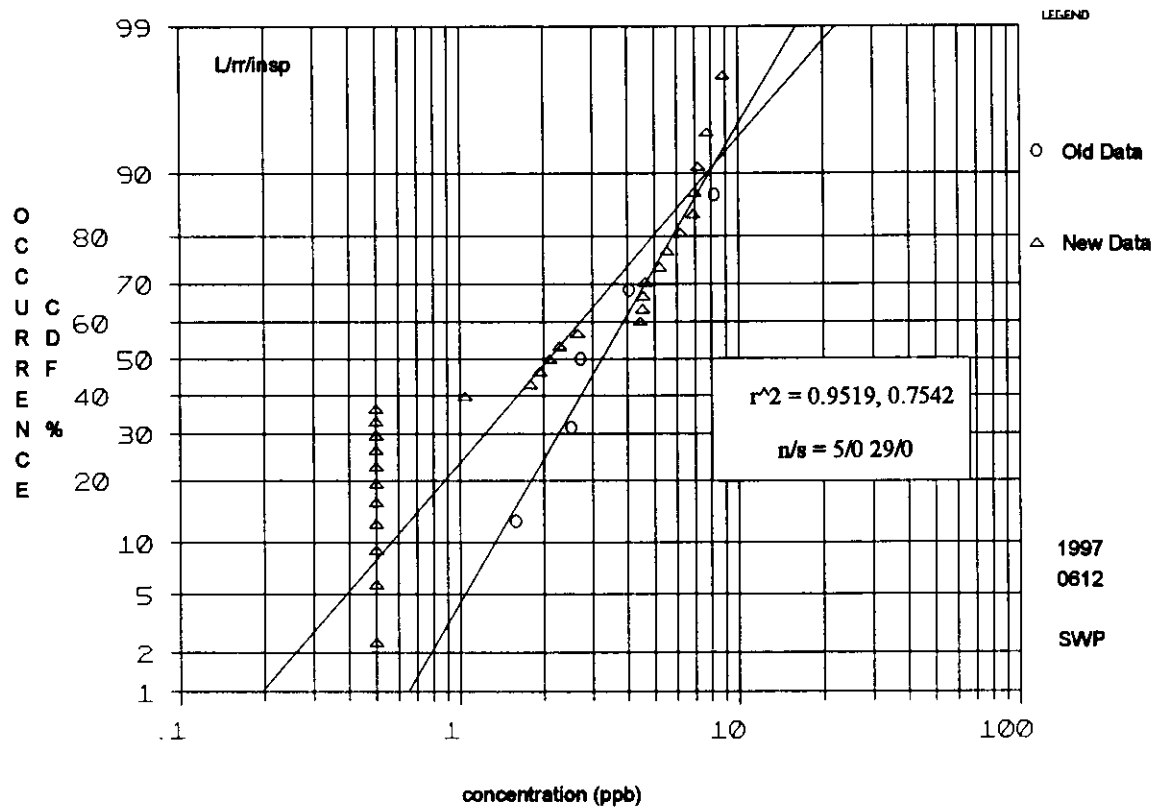
Figure 5-1. Probability Plot of Filtered Arsenic Values

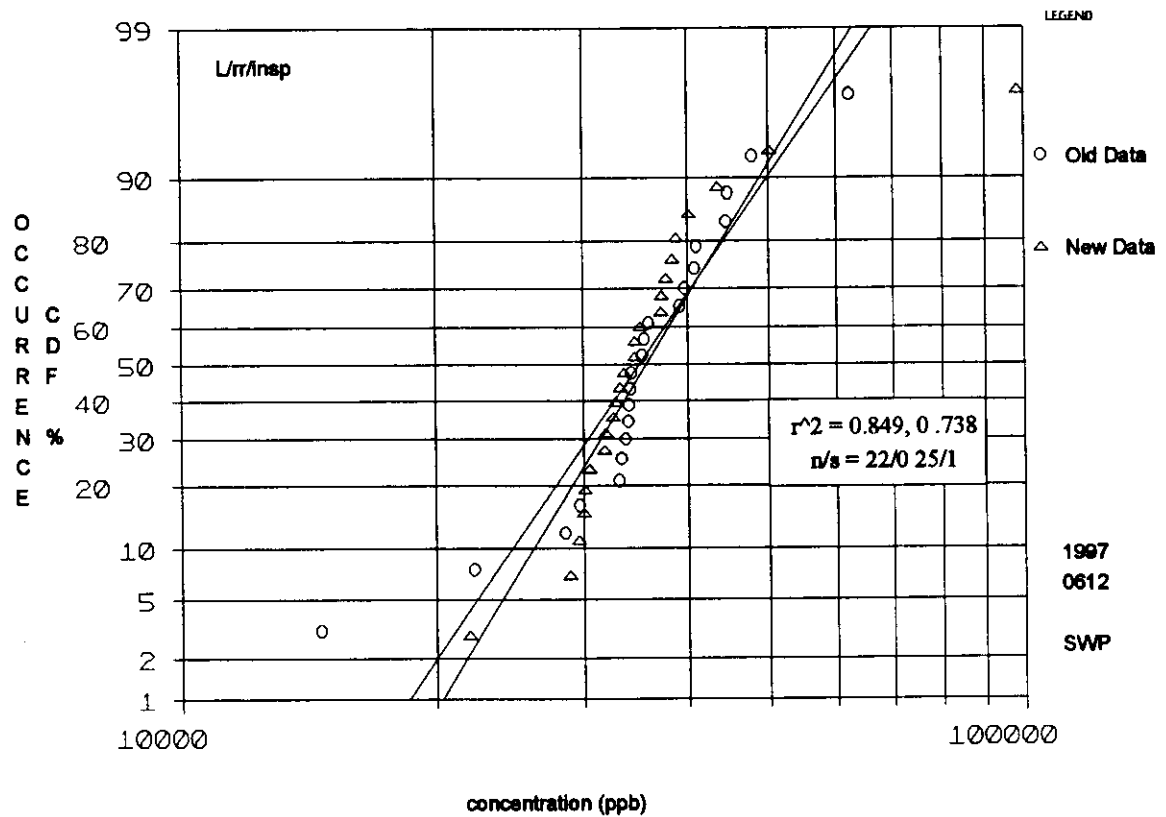
Figure 5-2. Probability Plot of Filtered Calcium Values

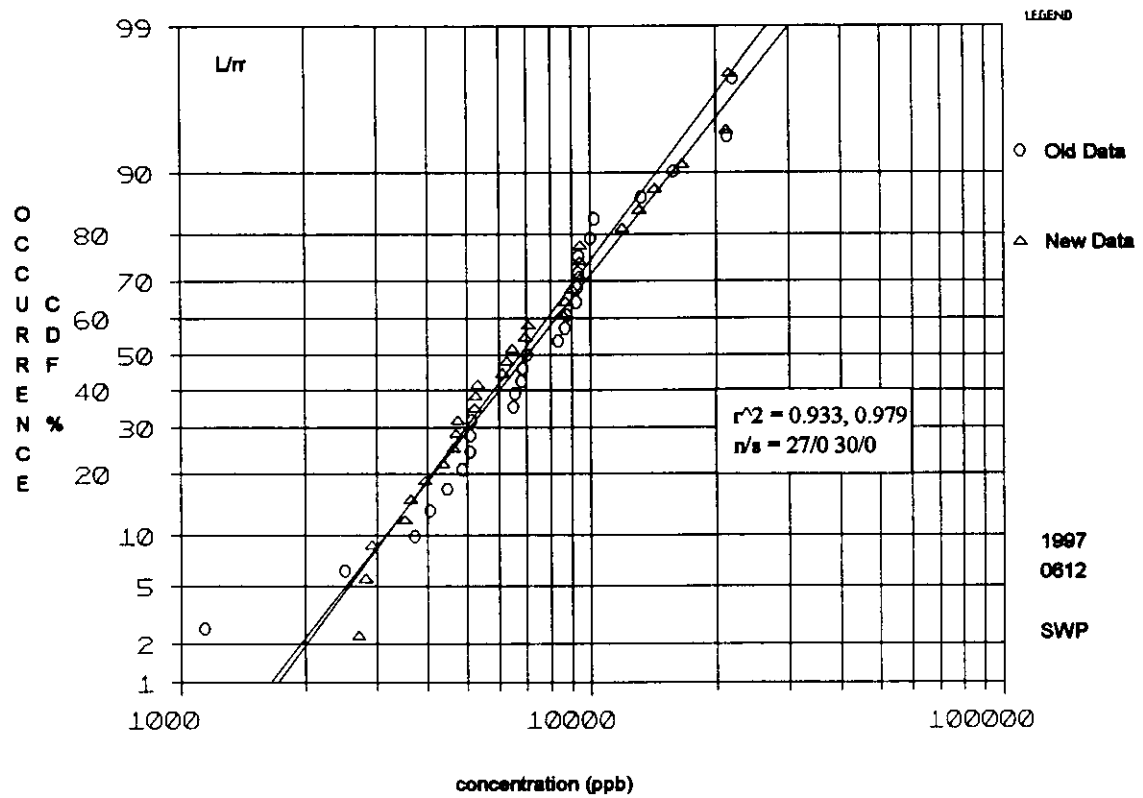
Figure 5-3. Probability Plot of Filtered and Unfiltered Chloride

Figure 5-4. Probability Plot of Filtered Chromium

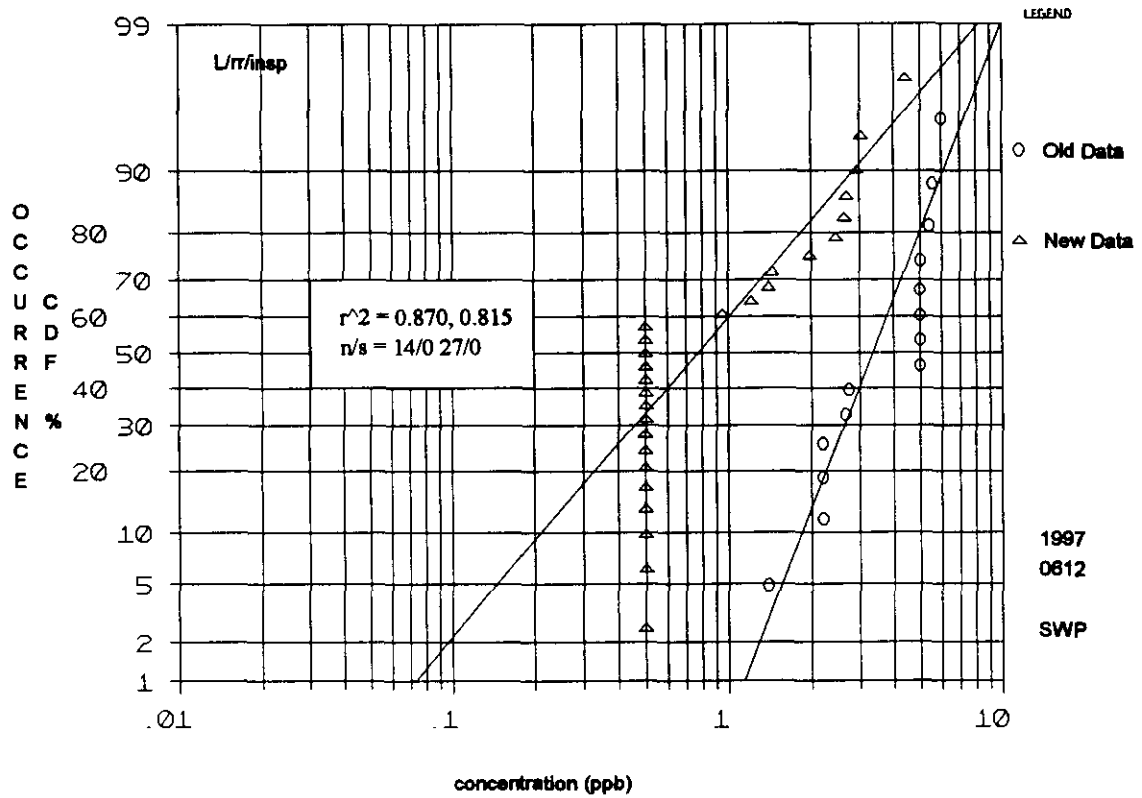


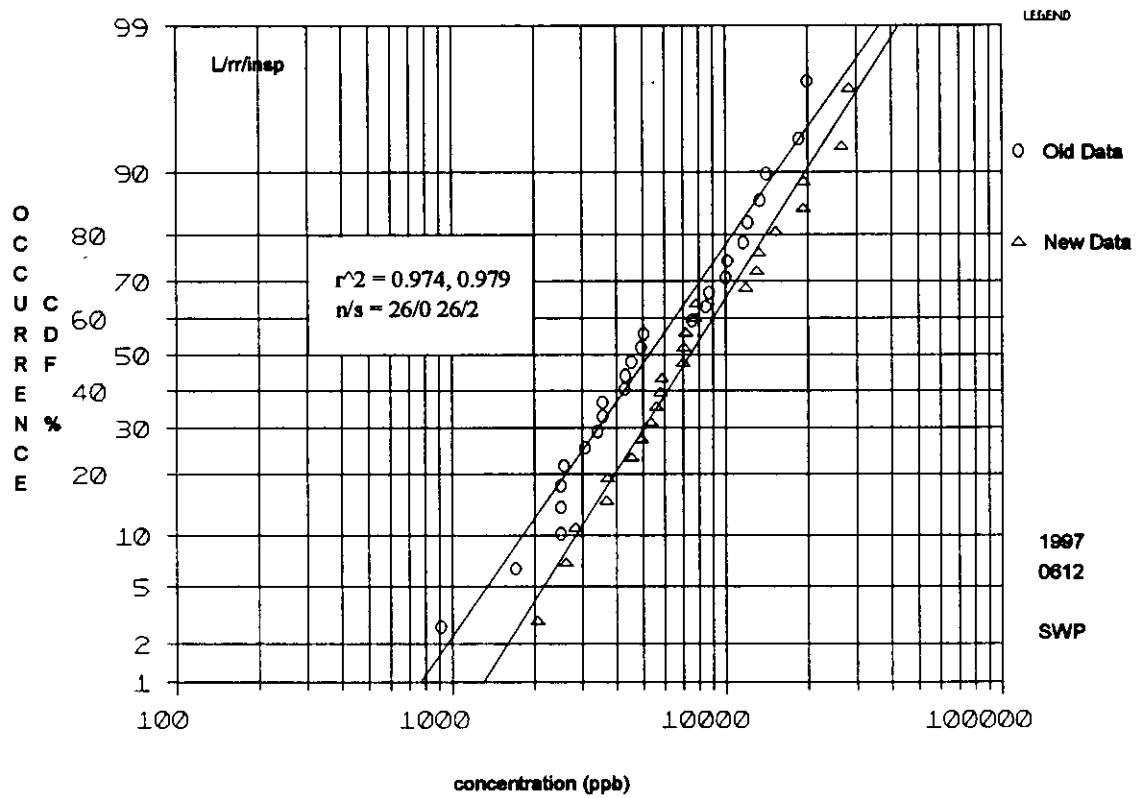
Figure 5-5. Probability Plot of Unfiltered Nitrate

Table 5-1. Summary Statistics for the Historic Set of Sideside Background Data (Page 1 of 7)

	Alkalinity	Aluminum	Ammonia	Antimony	Antimony-125	Arsenic	Barium	Beryllium	Beryllium-7	Boron
UNFILTERED	µg/L	µg/L	µg/L	µg/L	pCi/L	µg/L	µg/L	µg/L	pCi/L	µg/L
Geo. Mean	118983.97	42.89	32.90	20.99	17.76	3.40	31.51	0.56	6.42	33.57
Geo. Sd	1.28	1.96	1.62	2.34		1.67	1.78	1.96	1.26	1.94
Average	122411.96	51.14	37.50	31.31	17.76	3.87	36.30	0.70	6.55	43.29
Stdev	30872.04	27.87	25.88	34.66		2.26	18.11	0.53	1.52	39.31
n	23	9	8	11	1	10	24	11	4	20
Min	64975.00	16.75	25.00	9.47	17.76	1.74	10.00	0.30	5.25	17.00
Max	223333.33	85.57	100.00	100.00	17.76	9.20	76.18	1.53	8.30	161.00
50%	151721.57	84.17	53.44	49.03		5.69	56.20	1.09	8.09	65.08
90%	162485.61	101.79	61.28	62.29		6.57	66.17	1.32	8.64	78.44
95%	177473.20	130.02	73.08	84.76		7.92	81.63	1.68	9.40	99.75
FILTERED										
Geo. Mean	170000.00	32.47		23.79		3.24	28.70	0.58		20.33
Geo. Sd		1.84		1.92		1.85	2.12	2.91		1.56
Average	170000.00	38.78		28.97		3.81	35.77	1.00		22.30
Stdev		24.24		18.17		2.61	20.96	1.02		11.36
n	1	17		15		5	22	17		7
Min	170000.00	12.83		9.47		1.58	6.00	0.20		12.63
Max	170000.00	75.00		53.93		8.20	85.80	2.50		45.00
50%		59.71		45.78		6.00	60.84	1.70		31.74
90%		70.90		55.06		7.15	75.20	2.29		35.99
95%		88.44		69.82		8.94	98.78	3.38		42.30
	Detection Limit Statistics (All Values Before Averaging)									
Total	63	123	17	127	1	98	184	126	4	41
>DL	63	32	2	5	1	65	171	3	0	35
<DL	0	91	15	122	0	33	13	123	4	6
Min DL	0	14.7	50	11	0	2	8.2	0.1	10.5	10
Max DL	0	180	200	200	0	5	20	5	16.6	10
% < DL	0%	74%	88%	96%	0%	34%	7%	98%	100%	15%

Table 5-1. Summary Statistics for the Historic Set of Sitewide Background Data (Page 2 of 7)

	Bromide	Cadmium	Calcium	Cesium-134	Cesium-137	Chloride	Chromium	Cobalt	Cobalt-60	Conductivity
UNFILTERED	µg/L	µg/L	µg/L	pCi/L	pCi/L	µg/L	µg/L	µg/L	pCi/L	umhos/cm
Geo. Mean	156.93	1.55	36518.39	0.75	1.32	7052.13	7.04	3.29	1.61	347.85
Geo. Sd	3.08	2.11	1.33	1.39	2.05	1.86	2.05	1.91	2.41	1.41
Average	276.32	2.01	38058.40	0.78	1.61	8335.18	8.98	4.09	2.16	373.81
Stdev	298.94	1.58	12215.27	0.24	0.98	4953.89	7.55	3.17	1.62	193.52
n	23	11	25	4	7	27	9	11	7	35
Min	20.00	0.49	19200.00	0.50	0.51	1138.70	2.46	1.70	0.52	149.85
Max	1000.00	5.00	79683.33	1.06	3.09	21950.00	27.50	10.00	5.05	1361.20
50%	483.18	3.28	48574.89	1.03	2.69	13119.77	14.45	6.30	3.87	491.19
90%	663.50	4.05	52644.33	1.13	3.30	15629.85	17.70	7.57	4.96	541.38
95%	998.02	5.31	58388.51	1.28	4.27	19580.41	22.98	9.58	6.82	613.62
FILTERED										
Geo. Mean		1.17	35029.06				3.59	3.46		
Geo. Sd		1.40	1.33				1.61	2.39		
Average		1.23	36269.83				3.95	4.89		
Stdev		0.44	9324.40				1.60	3.94		
n		16	22				14	15		
Min		0.55	14600.00				1.38	1.33		
Max		2.50	62200.00				6.00	10.00		
50%		1.63	46462.74				5.80	8.28		
90%		1.79	50315.23				6.63	10.58		
95%		2.03	55748.22				7.89	14.52		
Detection Limit Statistics (All Values Before Averaging)										
Total	98	126	192	4	10	217	93	122	10	302
>DL	47	5	192	0	0	217	22	3	0	302
<DL	51	121	0	4	10	0	71	119	10	0
Min DL	30	0.98	0	0.991	1.019810771	0	1.8	1.3	1.03	0
Max DL	2000	10	0	2.11	6.176175626	0	20	20	10.1	0
% < DL	52%	96%	0%	100%	100%	0%	76%	98%	100%	0%

Table 5-1. Summary Statistics for the Historic Set of Sitewide Background Data (Page 3 of 7)

	Copper	Europium-154	Europium-155	Fluoride	Gross alpha	Gross beta	Iodine-129	Iron	Lead	Lithium
UNFILTERED	µg/L	pCi/L	pCi/L	µg/L	pCi/L	pCi/L	pCi/L	µg/L	µg/L	µg/L
Geo. Mean	6.43	2.39	1.67	491.30	1.51	4.63	0.11	156.49	2.64	
Geo. Sd	2.75	1.21	1.40	1.80	2.27	1.62	1.84	7.78	1.58	
Average	10.83	2.42	1.74	669.03	1.98	5.12	0.12	1806.25	2.91	
Stdev	12.94	0.49	0.54	1033.62	1.50	2.25	0.07	4993.09	1.39	
n	12	4	4	28	13	16	8	24	9	
Min	1.92	1.94	1.08	267.00	0.28	1.88	0.04	12.00	1.53	
Max	44.65	3.10	2.27	5850.00	5.89	9.77	0.24	21700.00	5.25	
50%	17.68	2.90	2.33	886.79	3.42	7.49	0.20	1217.20	4.18	
90%	23.51	3.06	2.56	1047.48	4.31	8.57	0.23	2170.66	4.76	
95%	33.94	3.28	2.90	1297.91	5.80	10.21	0.29	4570.69	5.63	
FILTERED										
Geo. Mean	3.66							55.32	1.68	5.00
Geo. Sd	1.41							6.17	1.30	1.00
Average	3.84							551.16	1.72	5.00
Stdev	1.10							1652.68	0.47	0.00
n	16							22	3	7
Min	1.48							6.00	1.33	5.00
Max	5.00							7225.00	2.24	5.00
50%	5.16							341.39	2.19	5.00
90%	5.69							570.35	2.36	5.00
95%	6.44							1104.22	2.60	5.00
Detection Limit Statistics (All Values Before Averaging)										
Total	132	4	4	234	37	42	11	178	95	21
>DL	22	0	0	210	19	30	2	126	41	0
<DL	110	4	4	24	18	12	9	52	54	21
Min DL	1.9	3.87	2.15	38	0.4	1.8	0.0755	3.7	0.8	10
Max DL	20	6.19	4.54	1000	2	7.28	0.0837	150	20	10
% < DL	83%	100%	100%	10%	49%	29%	82%	29%	57%	100%

Table 5-1. Summary Statistics for the Historic Set of Sitewide Background Data (Page 4 of 7)

	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Nitrate	Nitrite	pH	Phosphate	Potassium
UNFILTERED	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L		µg/L	µg/L
Geo. Mean	9722.31	19.38	0.15		9.39	5363.30	128.31	7.78	305.29	4578.06
Geo. Sd	1.41	4.50	3.94		1.55	2.19	4.70	1.04	2.31	1.71
Average	10210.48	48.03	0.80		10.16	7063.66	314.03	7.79	399.04	5095.80
Stdev	2878.29	62.83	2.22		3.83	5235.57	379.54	0.34	263.62	2052.62
n	25	17	10		11	26	23	35	25	25
Min	3450.00	1.82	0.07		4.42	910.43	11.00	6.94	51.67	767.92
Max	16266.67	222.00	7.11		15.00	19800.00	1000.00	8.79	1000.00	10000.00
50%	13731.45	87.23	0.57		14.56	11748.80	802.45	8.13	704.59	7838.74
90%	15135.66	133.34	0.85		16.48	14656.56	931.80	8.23	892.00	9122.45
95%	17156.63	230.23	1.39		19.33	19483.01	1633.55	8.36	1208.41	11089.08
FILTERED										
Geo. Mean	9959.79	5.30	0.08	20.00	5.76					4643.04
Geo. Sd	1.33	5.93	1.21	1.00	1.41					1.55
Average	10316.83	27.72	0.08	20.00	6.16					4967.81
Stdev	2634.24	56.49	0.02	0.00	2.79					1510.55
n	22	22	4	7	15					22
Min	4582.14	0.71	0.06	20.00	3.63					857.92
Max	15500.00	227.50	0.10	20.00	15.10					8030.00
50%	13217.91	31.43	0.10	20.00	8.14					7205.29
90%	14316.08	51.92	0.10	20.00	8.97					8155.89
95%	15865.04	99.07	0.11	20.00	10.17					9566.42
Detection Limit Statistics (All Values Before Averaging)										
Total	192	157	93	21	126	163	60	304	112	190
>DL	192	81	12	0	19	151	4	304	31	185
<DL	0	76	81	21	107	12	56	0	81	5
Min DL	0	0.7	0.1	40	2.6	240	10	0	72	372
Max DL	0	10	0.2	40	30	5000	2000	0	2000	5300
% < DL	0%	48%	87%	100%	85%	7%	93%	0%	72%	3%

Table 5-1. Summary Statistics for the Historic Set of Sitewide Background Data (Page 5 of 7)

	Potassium-40	Radium	Ruthenium-106	Selenium	Silicon	Silver	Sodium	Strontium (elemental)	Strontium-89
UNFILTERED	pCi/L	µg/L	pCi/L	µg/L	µg/L	µg/L	µg/L	µg/L	pCi/L
Geo. Mean	77.33	0.25	28.68	2.28	11921.69	3.43	13401.96	144.90	0.85
Geo. Sd	2.12	1.44	1.16	1.56	2.47	1.78	1.73	1.35	
Average	92.66	0.26	28.91	2.52	14875.00	4.10	15114.36	150.33	0.85
Stdev	47.00	0.10	3.99	1.34	8151.23	2.99	7003.65	46.46	
n	10	4	4	10	4	11	25	5	1
Min	11.95	0.17	23.13	1.42	3100.00	1.93	2360.00	101.67	0.85
Max	188.00	0.38	31.95	5.00	21900.00	10.00	32000.00	220.00	0.85
50%	163.90	0.36	33.24	3.54	29470.28	6.11	23143.07	195.77	
90%	202.58	0.40	34.66	4.01	38038.49	7.19	26997.66	213.11	
95%	266.08	0.46	36.56	4.71	52832.25	8.87	32919.16	237.71	
FILTERED									
Geo. Mean				3.35	13690.83	3.42	14317.33	169.98	
Geo. Sd				1.57	2.03	1.41	1.97	1.34	
Average				3.60	15916.61	3.60	18298.76	177.37	
Stdev				1.46	6855.32	1.16	18142.23	57.19	
n				4	7	15	22	14	
Min				1.88	2966.25	1.93	2378.57	98.63	
Max				5.09	23900.00	5.00	94600.00	331.00	
50%				5.27	27801.86	4.80	28231.32	228.58	
90%				5.99	33949.19	5.28	34188.83	248.50	
95%				7.06	43904.01	5.98	43744.33	276.71	
Detection Limit Statistics (All Values Before Averaging)									
Total	34	21	6	91	24	125	192	34	1
>DL	15	5	0	28	24	6	192	34	0
<DL	19	16	6	63	0	119	0	0	1
Min DL	23.9	0.066	38.6	0.9	0	2	0	0	1.7
Max DL	300	1	70.5	19	0	20	0	0	1.7
% < DL	56%	76%	100%	69%	0%	95%	0%	0%	100%

Table 5-1. Summary Statistics for the Historic Set of Sitewide Background Data (Page 6 of 7)

	Strontium-90	Sulfate	Sulfide	Technetium-99	Thallium	Tin	Titanium	Total Inorganic Carbon	Tritium	Turbidity
	pCi/L	µg/L	µg/L	pCi/L	µg/L	µg/L	µg/L	µg/L		NTU
UNFILTERED										
Geo. Mean	0.51	23024.00	430.59	0.45	1.37	29.66		24870.30	63.89	6.40
Geo. Sd	1.72	1.40	1.35	1.62	1.25	1.89		1.46	1.63	4.68
Average	0.58	24418.92	443.75	0.49	1.40	34.06		26140.00	71.06	19.61
Stdev	0.38	9619.72	112.50	0.23	0.36	18.75		7962.60	32.87	33.29
n	4	23	4	5	8	4		5	15	25
Min	0.38	10621.25	275.00	0.27	1.13	13.75		12900.00	27.77	0.56
Max	1.16	59320.00	500.00	0.75	2.23	50.00		33600.00	131.06	145.00
50%	0.88	32319.36	580.60	0.72	1.72	56.01		36368.15	104.03	29.96
90%	1.03	35562.83	631.67	0.83	1.83	67.00		40482.05	119.36	46.31
95%	1.25	40221.62	704.06	0.99	1.98	84.40		46469.94	142.47	81.12
FILTERED										
Geo. Mean					1.14	15.95	30.00			
Geo. Sd					1.35	1.27	1.00			
Average					1.18	16.43	30.00			
Stdev					0.39	4.91	0.00			
n					4	12	7			
Min					0.88	11.75	30.00			
Max					1.73	31.26	30.00			
50%					1.54	20.22	30.00			
90%					1.67	21.62	30.00			
95%					1.87	23.57	30.00			
Detection Limit Statistics (All Values Before Averaging)										
Total	19	179	9	5	89	39	21	5	104	81
>DL	1	179	0	2	20	0	0	5	36	81
<DL	18	0	9	3	69	39	21	0	68	0
Min DL	0.511883584	0	100	0	1	17	60	0	1.49320391	0
Max DL	7.980466711	0	1000	0	11	100	60	0	453.945969	0
% < DL	95%	0%	100%	60%	78%	100%	100%	0%	65%	0%

Table 5-1. Summary Statistics for the Historic Set of Silewide Background Data (Page 7 of 7)

	Uranium	Uranium-234	Uranium-235	Uranium-238	Vanadium	Zinc	Zirconium
UNFILTERED	µg/L	pCi/L	pCi/L	pCi/L	µg/L	µg/L	µg/L
Geo. Mean	1.31	0.75	0.32	1.59	10.39	15.85	
Geo. Sd	3.75	1.10	35.51	3.76	1.90	3.36	
Average	2.15	0.75	2.04	2.34	12.11	36.85	
Stdev	2.02	0.07	2.85	2.42	6.08	58.01	
n	23	2	2	2	11	16	
Min	0.01	0.70	0.03	0.62	2.35	4.12	
Max	8.71	0.80	4.05	4.05	22.84	197.25	
50%	4.92	0.83	11.52	5.97	19.79	53.30	
90%	7.14	0.85	31.53	8.67	23.74	75.02	
95%	11.54	0.88	115.21	14.02	29.99	116.50	
FILTERED							
Geo. Mean					8.14	13.67	25.00
Geo. Sd					1.81	3.68	1.00
Average					9.60	37.13	25.00
Stdev					5.78	78.32	0.00
n					21	21	7
Min					2.50	2.50	25.00
Max					21.68	358.00	25.00
50%					14.71	50.34	25.00
90%					17.39	72.70	25.00
95%					21.56	116.69	25.00
Detection Limit Statistics (All Values Before Averaging)							
Total	34	2	2	2	139	149	21
>DL	34	1	1	1	81	71	0
<DL	0	1	1	1	58	78	21
Min DL	0	1.4	8.1	8.1	3	2	50
Max DL	0	1.4	8.1	8.1	30.7	43.4	50
% < DL	0%	50%	50%	50%	42%	52%	100%

Table 5-2. Summary Statistics for the New Site-wide Background Data (Page 1 of 7)

	Alkalinity	Aluminum	Am-241	Ammonia	Arsenic	Barium	Beryllium	Bromide	Cadmium	Calcium
	µg/L	µg/L	fCi/liter	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
UNFILTERED										
Geo. Mean	118650	1.40		26.2	1.86	31.8	0.274	61.9	0.274	32422
Geo. Sd	1183	4.28		3120	3.02	2.61	2.57	1721	2.57	1.75
n	30	32		32	29	32	32	32	32	25
Average	120276	6.77		62.7	3.07	40.5	0.365	70.9	0.365	35876
Stdev	20321	20.4		155	2.63	21.1	0.189	40.5	0.189	14430
Min	80000	0.500		5.00	0.500	0.500	0.050	15.0	0.050	3030
Max	170000	104		882	7.66	90.8	0.500	235	0.500	90800
50%	140327	6.00		81.7	5.63	83.0	0.702	107	0.702	56703
90%	147127	9.04		113	7.69	109	0.916	124	0.916	66384
95%	156367	15.3		170	11.5	154	1.29	151	1.29	81319
FILTERED										
Geo. Mean	140285	1.23	0.732	27.2	1.83	31.2	0.274	141	0.274	32437
Geo. Sd	1211	3.92	2.11	3289	3.11	2.58	2.57	2036	2.57	1.71
n	3	32	16	32	29	32	32	32	32	25
Average	142000	7.58	0.841	65.5	3.10	39.9	0.365	185	0.365	35844
Stdev	27055	32.7	0.267	136	2.75	21.7	0.189	168	0.189	15415
Min	116000	0.500	0.050	5.00	0.500	0.500	0.050	50.0	0.050	3390
Max	170000	187	1.000	716	8.81	94.1	0.500	924	0.500	98300
50%	169829	4.84	1.54	89.4	5.70	80.7	0.702	288	0.702	55626
90%	179232	7.11	0.077	125	7.85	105	0.916	352	0.916	64764
95%	192108	11.7	0.080	193	11.8	149	1.29	455	1.29	78770
Detection Limit Statistics (All Values Before Averaging)										
Total	41	85	17	85	87	87	87	82	87	60
>DL	40	6	0	10	62	83	0	46	0	60
<DL	1	79	17	75	25	4	87	36	87	0
Min DL	2700	1	0.1	0.01	0.1	0.1	0.1	30	0.1	0
Max DL	2700	10	2	0.11	1	1	1	140	1	0
% < DL	2%	93%	100%	88%	29%	5%	100%	44%	100%	0%

Table 5-2. Summary Statistics for the New Sitewide Background Data (Page 2 of 7)

	Chloride	Chromium	Co-60	Cobalt	Conductivity	Copper	Cs-137	Cyanide	δ18O	δ3H
	µg/L	µg/L	fCi/L	µg/L	mS/cm	µg/L	fCi/L	µg/L	ppt	
UNFILTERED										
Geo. Mean	6768	1.04		0.280	314	0.333		5.43		
Geo. Sd	1773	2.45		2.48	1.21	2.36		1407		
n	30	27		32	31	32				
Average	7984	1.59		0.367	319	0.446		5.97	-17.152	-133.958
Stdev	5030	1.65		0.187	62.6	0.395		4.34	1.20	9.95
Min	2697	0.500		0.050	219	0.050		5.00		
Max	21508	7.24		0.500	462	2.41		26.7		
50%	12003	2.55		0.694	380	0.785		7.64		
90%	14108	3.29		0.897	401	1.00		8.41		
95%	17370	4.55		1.25	430	1.37		9.52		
FILTERED										
Geo. Mean	7147	0.893	1.09	0.274	284	0.332	2.26	5.44		
Geo. Sd	1737	2.16	2.43	2.57	1.04	2.01	2.79	1409		
n	30	27	17	32	2	32	17			
Average	8303	1.23	2.28	0.365	284	0.389	4.66	5.98	-16.990	-131.836
Stdev	4933	1.09	5.35	0.189	11.3	0.157	8.17	4.35	1.31	11.3
Min	2196	0.500	0.404	0.050	276	0.050	0.643	5.00		
Max	21739	4.41	23.0	0.500	292	0.500	29.5	26.7		
50%	12412	1.93	4.27	0.702	295	0.666	6.86	7.66		
90%	14503	2.40	22.5	0.916	299	0.810	8576	8.44		
95%	17721	3.17	44.7	1.29	303	1.04	58732	9.56		
	Detection Limit Statistics (All Values Before Averaging)									
Total	84	87	18	87		87	18	58	75	29
>DL	82	42	1	1		11	1	0	75	29
<DL	2	45	17	86		76	17	58	0	0
Min DL	180	0.1	1.3	0.1		0.1	1.4	10	0	0
Max DL	180	1	5.8	1		1	49	140	0	0
% < DL	2%	52%	94%	99%		87%	94%	100%	0%	0%

Table 5-2. Summary Statistics for the New Sitewide Background Data (Page 3 of 7)

	DO	Eh	Eu-152	Eu-154	Eu-155	Fluoride	Gross Alpha	Gross Beta	I-129	Iodine	Iron
UNFILTERED	µg/L	mv	fCi/L	fCi/L	fCi/L	µg/L	pCi/L	pCi/L	aCi/L	µg/L	µg/L
Geo. Mean	5306440	315				264	0.962	5.88	14.2	0.250	55.9
Geo. Sd	2117	1.38				1542	2.19	1.36	2.90	1.000	3.95
n	31	31				32	17	17	12	25	32
Average	6283280	328				295	1.26	6.15	24.1	0.250	264
Stdev	2535044	82.2				186	0.903	1.92	27.5		777
Min	380000	91.0				133	0.200	3.77	3.10	0.250	5.00
Max	9440000	510				1188	2.76	9.64	93.1	0.250	3770
50%	11231878	434				407	2.10	7.99	41.2	0.250	221
90%	13876675	476				460	2.62	8.71	55.6	0.250	325
95%	18217806	535				539	3.48	9.73	81.9	0.250	535
FILTERED											
Geo. Mean	4157499	382	12.9	8.00	2.33	271	1.09	5.60	28.8	0.250	44.0
Geo. Sd	1776	1.36	1.51	1.52	1.87	1539	2.03	1.33	2.51	1.000	2.71
n	2	2	17	17	17	32	19	19	9	25	32
Average	4505000	392	13.9	8.67	2.90	302	1.33	5.83	40.9	0.250	84.3
Stdev	2453661	118	5.42	3.67	2.52	186	0.796	1.75	34.0		183
Min	2770000	308	5.39	3.43	0.969	123	0.250	3.39	6.30	0.250	5.00
Max	6240000	475	24.1	18.3	11.7	1185	3.02	9.45	96.1	0.250	1028
50%	7382988	520	23.4	16.3	7.39	417	2.23	7.42	72.4	0.250	119
90%	8680864	566	222128	69517	5932	471		3.10	0.900	0.250	158
95%	10692891	633	5620950	751469	35471	551		4.15	0.950	0.250	227
Detection Limit Statistics (All Values Before Averaging)											
Total	38	38	18	18	18	84	49	49	28	58	87
>DL	38	38	0	0	1	82	40	48	28	0	9
<DL	0	0	18	18	17	2	9	1	0	58	78
Min DL	0	0	13	9.2	3.3	500	0.18	0.63	0	500	0.1
Max DL	0	0	58	49	18	500	1.3	0.63	0	500	100
% < DL	0%	0%	100%	100%	94%	2%	18%	2%	0%	100%	90%

Table 5-2. Summary Statistics for the New Site-wide Background Data (Page 4 of 7)

	K-40	Lead	Lithium	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Nitrate	Nitrite
UNFILTERED	pCi/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Geo. Mean		0.373	5.73	11199	2.37		0.841	0.823	5681	29.2
Geo. Sd		3.79	1.70	1.90	9.72	3.63	2.68	2.68	3361	2483
n		31	30	25	32	27	25	32	26	32
Average		1.24	6.61	12749	14.1	0.001	1.61	1.40	8875	51.6
Stdev		3.62	3.92	6217	23.0	0.001	2.52	1.96	7457	107
Min		0.050	2.38	723	0.050		0.500	0.050	85.0	10.00
Max		19.6	19.0	38900	91.8	0.005	10.7	10.1	28063	629
50%		1.42	9.75	21295	23.0	0.002	2.26	2.21	19091	72.5
90%		2.06	11.3	25526	43.7	0.002	2.98	2.91	26871	93.7
95%		3.35	13.7	32233	99.8	0.004	4.27	4.16	41723	130
FILTERED										
Geo. Mean	1.98	0.271	5.88	11245	2.22		0.862	0.686	5668	30.4
Geo. Sd	2.43	2.59	1.75	1.85	9.25	5.34	2.79	1.90	3529	2169
n	18	31	30	25	32	27	25	31	26	32
Average	2.65	0.363	6.89	12741	14.5	0.002	1.73	0.867	8821	39.0
Stdev	1.89	0.190	4.14	6318	25.5	0.003	2.74	0.695	6912	26.1
Min	0.160	0.050	2.46	825	0.050		0.500	0.270	85.0	10.00
Max	6.40	0.500	18.6	39600	94.4	0.012	11.6	2.56	27524	122
50%	4.81	0.701	10.3	20850	20.6	0.002	2.41	1.31	20005	65.8
90%	2395	0.917	12.1	24816	38.5	0.003	3.21	1.56	28549	81.9
95%	13584	1.30	14.8	31051	86.4	0.006	4.67	1.98	45124	108
Detection Limit Statistics (All Values Before Averaging)										
Total	19	87	81	60	87	71	58	87	84	82
>DL	19	8	79	60	62	51	14	46	81	4
<DL	0	79	2	0	25	20	44	41	3	78
Min DL	0	0.1	100	0	0.1	0.0001	1	0.1	170	20
Max DL	0	1	100	0	1.75	0.0001	1	1	250	110
% < DL	0%	91%	2%	0%	29%	28%	76%	47%	4%	95%

Table 5-2. Summary Statistics for the New Site-wide Background Data (Page 5 of 7)

	Oxalate	pH	Phosphate	Plutonium	Pu-238	Pu-239+240	Ra-226	Ra-228(Ac-228)	Ru-106	Sb-125
UNFILTERED	µg/L		µg/L	µg/L	fCi/liter	fCi/liter	fCi/L	fCi/L	fCi/L	fCi/L
Geo. Mean	161	7.65	102	0.004						
Geo. Sd	1566	1.03	1432	2.15						
n	32	31	32	25						
Average	178	7.66	109	0.004						
Stdev	77.7	0.242	44.2	0.001						
Min	95.0	6.77	65.0	0.001						
Max	280	8.08	293	0.005						
50%	253	7.91	146	0.008						
90%	287	7.98	162	0.010						
95%	338	8.07	184	0.013						
FILTERED										
Geo. Mean	160	7.73	98.2	0.004	0.064	0.398	18.2	32.3	1.63	3.77
Geo. Sd	1579	1.00	1375	2.15	2.64	1.97	1.60	1.72	1.89	1.61
n	32	2	32	25	16	16	17	17	17	17
Average	177	7.73	103	0.004	0.103	0.456	20.1	36.9	1.98	4.20
Stdev	78.6	0.028	30.2	0.001	0.122	0.177	9.05	19.2	1.40	2.08
Min	95.0	7.71	65.0	0.001	0.015	0.040	7.00	12.8	0.607	1.73
Max	280	7.75	140	0.005	0.485	0.762	41.5	75.6	5.92	8.97
50%	252	7.76	135	0.008	0.173	0.784	29.1	86.3	38.3	15.5
90%	287	7.77	148	0.010	0.499		1063		128447	
95%	339	7.78	166	0.013	0.532		5179		3061043	
Detection Limit Statistics (All Values Before Averaging)										
Total	82	38	82	58	17	17	18	18	18	18
>DL	0	38	1	0	8	15	0	17	0	0
<DL	82	0	81	58	9	2	18	1	18	18
Min DL	150	0	100	0.001	0.03	0.08	14	40	16	8.8
Max DL	560	0	280	0.01	1	1	83	40	150	46
% < DL	100%	0%	99%	100%	53%	12%	100%	6%	100%	100%

Table 5-2. Summary Statistics for the New Sited Background Data (Page 6 of 7)

	Selenium	Sodium	Sr-90	Strontium	Sulfate	Sulfide	TC	TDS	Technetium	Temp.
UNFILTERED	µg/L	µg/L	fCi/liter	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	Centigrade
Geo. Mean	1.06	10037		157	27102	1.83	30325	200919	0.005	18.9
Geo. Sd	6.67	2.27		1.78	1537	1.35	1174	1.22	1.00	1.11
n	32	25		32	28	32	32	30	25	31
Average	3.26	12787		176	29741	1.94	30701	204700	0.005	19.0
Stdev	3.50	7902		76.4	13998	0.797	4888	40686		2.00
Min	0.050	930		11.8	11190	1.60	20990	140000	0.005	14.8
Max	11.0	36000		451	71212	5.12	43175	295000	0.005	23.7
50%	7.05	22809		280	41649	2.48	35591	244332	0.005	21.0
90%	12.0	28750		329	47014	2.70	37234	258189	0.005	21.6
95%	24.0	38730		406	54950	3.02	39462	277190	0.005	22.4
FILTERED										
Geo. Mean	0.960	10094	4.78	158	28474	1.71	32142	181931	0.005	19.5
Geo. Sd	6.47	2.24	2.39	1.75	1481	1.21	1213	1.04	1.00	1.09
n	32	25	14	32	28	32	32	2	25	2
Average	2.99	12852	6.34	176	30782	1.75	32737	182000	0.005	19.5
Stdev	3.39	8262	4.38	73.8	13283	0.429	6530	7071		1.75
Min	0.050	1010	0.641	13.1	15329	1.60	22110	177000	0.005	18.3
Max	11.6	38800	15.6	402	72023	3.21	53130	187000	0.005	20.8
50%	6.21	22581	12.4	276	42175	2.08	38993	189141	0.005	21.3
90%	10.5	28338	1.03	323	47116	2.19	41177	191225	0.005	21.9
95%	20.7	37958	1.14	396	54337	2.35	44169	193942	0.005	22.6
Detection Limit Statistics (All Values Before Averaging)										
Total	87	60	15	85	84	82	83	36	58	38
>DL	44	60	14	83	82	1	83	36	0	38
<DL	43	0	1	2	2	81	0	0	58	0
Min DL	0.1	0	1.4	0.1	210	3.2	0	0	0.01	0
Max DL	5	0	1.4	0.1	210	6.42	0	0	0.01	0
% < DL	49%	0%	7%	2%	2%	99%	0%	0%	100%	0%

Table 5-2. Summary Statistics for the New Silewide Background Data (Page 7 of 7)

	Thorium	TIC	TOC	Tritium	U-235	U-238	Uranium	Vanadium	Zinc
UNFILTERED	µg/L	µg/L	µg/L	pCi/L	fCi/L	fCi/L	µg/L	µg/L	µg/L
Geo. Mean	0.500	28722	1293	101			2.68	1.85	2.96
Geo. Sd	1.000	1166	1779	1.26			2.72	4.27	9.06
n	25	32	32	14			25	32	32
Average	0.500	29044	1596	103			4.02	4.53	67.1
Stdev		4354	1403	26.5			3.42	5.33	265
Min	0.500	19550	560	81.2			0.500	0.500	0.500
Max	0.500	39020	6720	163			13.4	20.5	1480
50%	0.500	33477	2300	156			7.28	7.91	26.9
90%	0.500	34955	2706	167			9.64	11.9	50.0
95%	0.500	36953	3336	182			13.9	20.2	111
FILTERED									
Geo. Mean	0.500	28462	2412	113	23.1	721	2.57	1.83	1.27
Geo. Sd	1.000	1167	2232	1.31	3.34	1.89	2.85	4.19	8.22
n	25	32	32	16	17	17	25	32	32
Average	0.500	28787	3551	117	38.1	858	3.98	4.32	53.3
Stdev		4359	4311	36.5	33.1	531	3.41	4.78	227
Min	0.500	19470	710	81.5	1.55	150	0.500	0.500	0.050
Max	0.500	38835	23020	228	114	2440	12.8	16.7	1270
50%	0.500	33213	5382	179	77.0	1363	7.33	7.68	11.7
90%	0.500	34691	6750	53.7			9.85	11.5	21.8
95%	0.500	36691	9033	102			14.4	19.3	48.9
Detection Limit Statistics (All Values Before Averaging)									
Total	58	83	83	42	18	18	58	87	85
>DL	0	83	83	4	12	12	49	38	39
<DL	58	0	0	38	6	6	9	49	46
Min DL	1	0	0	200	3.1	300	1	0.1	0.1
Max DL	1	0	0	320	19	1100	1	1	1
% < DL	100%	0%	0%	90%	33%	33%	16%	56%	54%

Table 5-3. Organic Constituents Analyzed for Samples Collected in 1993 and 1994

Volatiles:	Semi Volatiles:	
1,1,1-Trichloroethane 1,1,2,2-Tetrachloroethane 1,1,2-Trichloroethane 1,1-Dichloroethane 1,1-Dichloroethene 1,2-Dichloroethane 1,2-Dichloroethene (total) 1,2-Dichloropropane 2-Butanone 2-Hexanone 4-Methyl-2-pentanone Acetone Benzene Bromodichloromethane Bromoform Bromomethane Carbon Disulfide Carbon Tetrachloride Chlorobenzene Chloroethane Chloroform Chloromethane cis-1,3-Dichloropropene Dibromochloromethane	1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,3-Dichlorobenzene 1,4-Dichlorobenzene 2,4,5-Trichlorophenol 2,4,6-Trichlorophenol 2,4-Dichlorophenol 2,4-Dimethylphenol 2,4-Dinitrophenol 2,4-Dinitrotoluene 2,6-Dinitrotoluene 2-Chloronaphthalene 2-Chlorophenol 2-Methylnaphthalene 2-Methylphenol 2-Nitroaniline 2-Nitrophenol 3,3'-Dichlorobenzidine 3-Nitroaniline 4,6-Dinitro-2-methylphenol 4-Bromophenyl-phenylether 4-Chloro-3-methylphenol 4-Chloroaniline 4-Chlorophenyl-phenylether	Benzo(k)fluoranthene Benzoic acid Benzyl alcohol bis(2-Chloroethoxy)methane bis(2-Chloroethyl)ether bis(2-Chloroisopropyl)ether bis(2-Ethylhexyl)phthalate Butylbenzylphthalate Chrysene Di-n-Butylphthalate Di-n-Octyl phthalate Dibenzo(a,h)anthracene Dibenzofuran Diethylphthalate Dimethylphthalate Fluoranthene Fluorene Hexachlorobenzene Hexachlorobutadiene Hexachlorocyclopentadiene Hexachloroethane Indeno(1,2,3-cd)pyrene Isophorone N-Nitroso-Di-n-propylamine
Ethylbenzene Methylene Chloride Styrene Tetrachloroethene Toluene Trans-1,3-Dichloropropene Trichloroethene Vinyl Acetate Vinyl Chloride Xylene (total)	4-Methylphenol 4-Nitroaniline 4-Nitrophenol Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b)fluoranthene Benzo(g,h,i)perylene	N-Nitrosodiphenylamine (1) Naphthalene Nitrobenzene Pentachlorophenol Phenanthrene Phenol Pyrene

6.0 SUMMARY AND CONCLUSIONS

The data presented and evaluated in this report represent an attempt to characterize the range of groundwater background concentrations for the Hanford Site. Defining background on a sitewide basis offers several advantages over the more commonly used method of defining background for individual WMUs. Specifically, evaluating background on a sitewide basis offers a more technically defensible approach for establishing background conditions, particularly in terms of representing the range of groundwater analyte concentrations that exist naturally. Groundwater composition is dependent largely on common natural processes that occur in an aquifer. Because the unconfined aquifer beneath the Hanford Site is one system, the range of groundwater compositions that exist within the aquifer are best be characterized on the scale of the entire aquifer. This concept is more thoroughly developed in Chapter 2.0 and in associated references.

Sitewide groundwater background was characterized with data obtained from historical analyses reported in HEIS and from new samples collected specifically for the purpose of defining background concentrations. All data were examined using a rigorous screening process to eliminate information that may not be representative of background conditions. This process included censoring data from wells located in areas in which the groundwater was potentially contaminated by Hanford Site operations and eliminating wells that may have had natural levels of constituents diluted by artificial recharge. The well selection and screening process resulted in the largest and most relevant data set yet assembled for characterizing groundwater background at the Hanford Site. These data provide the most accurate representation of the background distribution for chemicals and radionuclides in groundwater in the unconfined aquifer.

The new data were analyzed using techniques that provided lower detection limits than generally realized in routine groundwater analysis. These more sensitive analytical techniques were employed in this study for the purpose of establishing true background conditions for the many analytes with background concentrations below typical detection limits. The techniques used to achieve these lower detection limits are not practical to employ in routine monitoring or remediation.

After these data were assembled, they were stratified into filtered and unfiltered subsets. The distributions of the data were then evaluated and found to follow a lognormal distribution in nearly all cases. The data were statistically summarized by computing averages for each analyte in each well, then using these averages to compute the arithmetic mean and standard deviation, geometric mean and standard deviation, minimum, maximum, and 90th and 95th percentiles. Data reported as equal to or below the detection limit were assigned a value of one-half the detection limit.

Many of the analytes in both the historical and new data sets contain values for unfiltered and filtered samples, and a summary of all of these data are presented in Chapter 5.0. In an effort to produce a summary of data in the most useful format, one set of statistics for each analyte is

presented in Table 6-1. The data sets on which the statistics are based are identified in Table 6-1 and were chosen based on their representativeness and anticipated typical uses. In general, filtered samples were used for metals and unfiltered samples were used for anions. The new radionuclide data were obtained from filtered samples.

Although these data represent the best effort to date for defining the range of groundwater background compositions, they are not sufficiently complete to evaluate the degree of spatial variability throughout the unconfined aquifer. Most of the wells were screened in the upper 3 to 5 m (10 to 16 ft) of the aquifer, which precludes any assessment of vertical variability in groundwater composition. Significant vertical variability in the natural composition of groundwater has been shown to exist on a scale of a few centimeters within the upper 15 m (50 ft) of this unconfined aquifer (Hoover and McKinley 1995). The concentrations of some analytes differ by more than a factor of 5 over a vertical distance of 30 cm (12 in.). Lateral variability has also been shown to contribute significantly to the chemical variation across the Hanford Site when compared with seasonal and analytical sources of variation (Johnson et al. 1994).

This lateral variability may indicate the existence of specific compositional domains within the aquifer. For example, groundwater chemistry in wells near the Columbia River may be influenced by side-bank recharge. An evaluation of the existence of discrete populations across the Hanford Site was conducted but produced no firm conclusions because of the limited number of wells in the various areas of interest. Figure 6-1 is a cumulative distribution plot comparing chloride and nitrate levels from wells in the 100 Areas between 100-D and 100-H, the 200 Areas, and the 300 Areas. These plots show that the data overlap for all three areas, but there are too few data to declare the three areas as distinct populations or indistinguishable from each other. A rigorous statistical treatment is unwarranted because of the paucity of data.

It remains a possibility that "local backgrounds" exist in one or more areas of the Hanford Site, but this may not be a significant issue if the tenets of the sitewide conceptual model are accepted. Because the unconfined aquifer beneath the Hanford Site is one system, the compositional variations in this system can be determined and applied to the entire Site. Local compositional variations are expected to be present, but should occur within the range determined in this study.

The background data presented here can be used as a screening criterion to evaluate groundwater contamination and as possible cleanup limits. The latter is allowed by MTCA if regulatory limits are below background (WAC 173-340-700-[4][d]). These regulations also allow the use of alternative statistical techniques to compare the background data set with data from a WMU, upon acceptance of the alternative method by the state. These alternative statistical tests include hypothesis tests such as the Wilcoxon Rank Sum and the Quantile tests, which consider all of the data from both the background and WMU data sets to determine if they are similar or if one is fundamentally larger or smaller. These tests hold an advantage over the MTCA approach of using a single value to define background by treating the data as a range of compositions (a statistical distribution) and allowing better control on the error rates of the tests. It is recommended that these tests be used when background is used as a cleanup limit; the upper percentile is best employed as a screening tool when defining an initial list of possible

contaminants at a WMU. Details of these tests and justification for their use can be found in Hardin and Gilbert (1993), Petersen (BHI 1995), and DOE/RL-94-72 (DOE-RL 1994).

A comparison of background values for analytes that exceed some regulatory limit is presented in Table 6-2. This table shows that the upper values for historical background data exceed current groundwater regulatory standards for antimony, arsenic, beryllium, lead, mercury, selenium, and, thallium. The new groundwater data exceed one or more regulatory limits for arsenic, beryllium, and selenium. The new data are clearly of higher quality than the historic data for most metals and all radionuclides because their lower detection limits allow a more accurate appraisal of groundwater compositions. It is recommended that the data presented here be used for all appropriate applications concerning groundwater background compositions in this region.

Figure 6-1. Comparison of Background Values for Chloride and Nitrate from Wells in the 100 Areas, 200 Areas, and 300 Areas

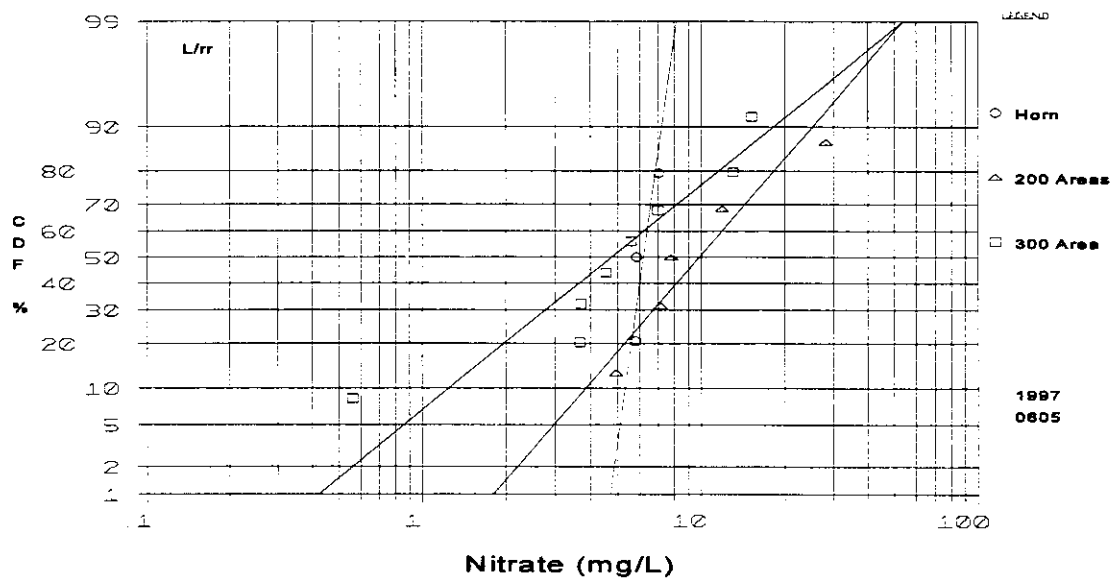
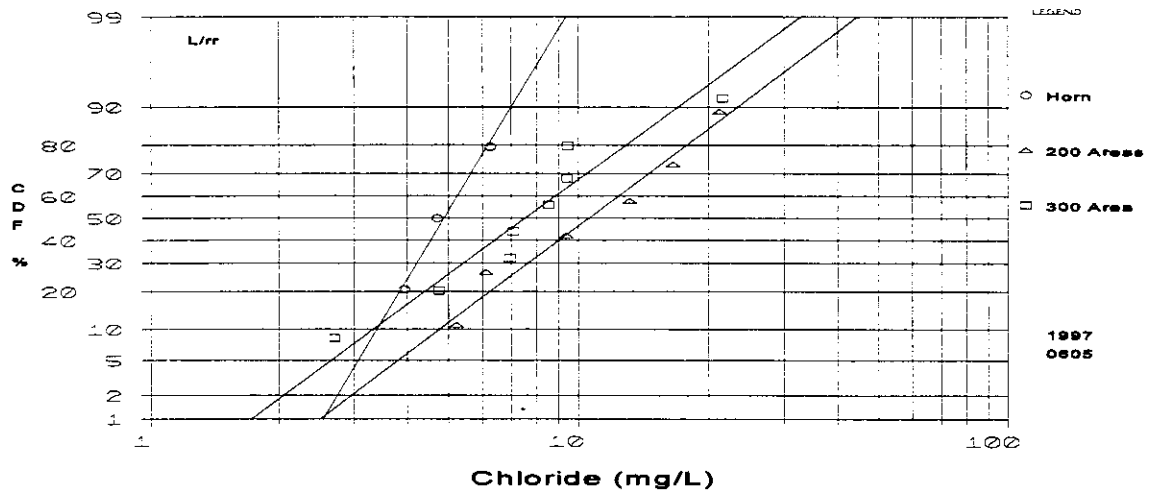


Table 6-1. Selected Summary Statistics for Groundwater Background (Page 1 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Alkalinity	New	More data	Unfiltered	µg/L	118650	1183	30	80000	170000	147127	156367
Aluminum	New	Lower DL	Filtered	µg/L	1.23	3.92	32	0.5	187	7.11	11.7
Americium-241*	New	Lower DL	Filtered	IC/L	0.732	2.11	16	0.05	1	0.077	0.08
Ammonia	New	Lower DL	Unfiltered	µg/L	26.2	3120	32	5	882	113	170
Antimony	Historical	No new	Filtered	µg/L	23.8	1.92	15	9.47	53.9	55.1	69.8
Antimony-125	New	Lower DL	Filtered	IC/L	3.77	1.61	17	1.73	8.97	0	0
Arsenic	New	Lower DL	Filtered	µg/L	1.83	3.11	29	0.5	8.81	7.85	11.8
Barium	New	Lower DL	Filtered	µg/L	31.2	2.58	32	0.5	94.1	105	149
Beryllium	Historical	More > DL	Filtered	µg/L	0.583	2.91	17	0.2	2.5	2.29	3.38
Beryllium-7	Historical	No new	Unfiltered	pCi/L	6.42	1.26	4	5.25	8.3	8.64	9.4
Boron	Historical	No new	Filtered	µg/L	20.3	1.56	7	12.6	45	36	42.3
Bromide	New	Lower DL	Unfiltered	µg/L	61.9	1721	32	15	235	124	151
Cadmium	New	Lower DL	Filtered	µg/L	0.274	2.57	32	0.05	0.5	0.916	1.29
Calcium	Historical	More data	Unfiltered	µg/L	36518	1.33	25	19200	79683	52644	58389
Cesium-134	Historical	No new	Unfiltered	pCi/L	0.747	1.39	4	0.496	1.06	1.13	1.28
Cesium-137	New	Lower DL	Filtered	IC/L	2.26	2.79	17	0.643	29.5	8576	58732
Chloride	Historical	More data	Unfiltered	µg/L	7052	1.86	27	1139	21950	15630	19580
Chromium	New	Lower DL	Filtered	µg/L	0.893	2.16	27	0.5	4.41	2.4	3.17
Cobalt	New	Lower DL	Filtered	µg/L	0.274	2.57	32	0.05	0.5	0.916	1.29
Cobalt-60*	New	Lower DL	Filtered	IC/L	1.09	2.43	17	0.404	23	22.5	44.7
Conductivity	Historical	More data	Unfiltered	mS/cm	348	1.41	35	150	1361	541	614
Copper	New	Lower DL	Filtered	µg/L	0.332	2.01	32	0.05	0.5	0.81	1.04
Cyanide	New	No Historical	Unfiltered	µg/L	5.43	1407	25	5	26.7	8.41	9.52
DO	New	No Hist.	Unfiltered	µg/L	5306	2117	31	380	9440	13877	18218
Eh	New	No Hist.	Unfiltered	mv	315	1.38	31	91	510	476	535
Europium-152	New	Lower DL	Filtered	IC/L	12.9	1.51	17	5.39	24.1	222128	5620950
Europium-154	New	Lower DL	Filtered	IC/L	8	1.52	17	3.43	18.3	69517	751469

Table 6-1. Selected Summary Statistics for Groundwater Background (Page 2 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Europium-155	New	Lower DL	Filtered	fCi/L	2.33	1.87	17	0.969	11.7	5932	35471
Fluoride	Historical	More data	Unfiltered	µg/L	491	1.8	28	267	5850	1047	1298
Gross alpha	New	More data	Filtered	pCi/L	1.09	2.03	19	0.25	3.02	0	0
Gross beta	New	More data	Filtered	pCi/L	5.6	1.33	19	3.39	9.45	3.1	4.15
Iodine	New	No Hist.	Unfiltered	µg/L	250	1000	25	250	250	250	250
Iodine-129	New	Lower DL	Filtered	aCi/L	28.8	2.51	9	6.3	96.1	0.9	0.95
Iron	Historical	More data	Filtered	µg/L	55.3	6.17	22	6	7225	570	1104
Lead	New	Lower DL	Filtered	µg/L	0.271	2.59	31	0.05	0.5	0.917	1.3
Lithium	New	More data	Unfiltered	µg/L	5729	1701	30	2380	19000	11321	13729
Magnesium	New	More data	Filtered	µg/L	11245	1.85	25	825	39600	24816	31051
Manganese	New	More data	Filtered	µg/L	2.22	9.25	32	0.05	94.4	38.5	86.4
Mercury	New	Lower DL	Filtered	µg/L	0	5.34	27	0	0.012	0.003	0.006
Molybdenum	New	Lower DL	Filtered	µg/L	0.862	2.79	25	0.5	11.6	3.21	4.67
Nickel	New	Lower DL	Filtered	µg/L	0.686	1.9	31	0.27	2.56	1.56	1.98
Nitrate	New	More data	Unfiltered	µg/L	5681	3361	26	85	28063	26871	41723
Nitrite	New	More data	Unfiltered	µg/L	29.2	2483	32	10	629	93.7	130
Oxalate	New	No Hist.	Unfiltered	µg/L	161	1566	32	95	280	287	338
pH	Historical	More data	Unfiltered	0	7.78	1.04	35	6.94	8.79	8.23	8.36
Phosphate	New	Lower DL	Unfiltered	µg/L	102	1432	32	65	293	162	184
Plutonium	New	No Hist.	Filtered	µg/L	0038	2.15	25	0.001	0.005	0.01	0.013
Plutonium-238	New	Lower DL	Filtered	fCi/L	0.064	2.64	16	0.015	0.485	0.499	0.532
Plutonium-239/ 240	New	Lower DL	Filtered	fCi/L	0.398	1.97	16	0.04	0.762	0	0
Potassium	Historical	No new	Unfiltered	µg/L	4578	1.71	25	768	10000	9122	11089
Potassium-40	Historical	No new	Unfiltered	pCi/L	77.3	2.12	10	12	188	203	266
Radium-226	New	Lower DL	Filtered	fCi/L	18.2	1.6	17	7	41.5	1063	5179
Radium-228	New	Lower DL	Filtered	fCi/L	32.3	1.72	17	12.8	75.6	0	0

Table 6-1. Selected Summary Statistics for Groundwater Background (Page 3 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Ruthenium-106	New	Lower DL	Filtered	fCi/L	1.63	1.89	17	0.607	5.92	128447	3061043
Selenium	New	Lower DL	Filtered	µg/L	0.96	6.47	32	0.05	11.6	10.5	20.7
Silicon	Historical	No new	Filtered	µg/L	13691	2.03	7	2966	23900	33949	43904
Silver	Historical	No new	Filtered	µg/L	3.42	1.41	15	1.93	5	5.28	5.98
Sodium	Historical	More data	Unfiltered	µg/L	13402	1.73	25	2360	32000	26998	32919
Strontium (elemental)	New	More data	Filtered	µg/L	158	1.75	32	13.1	402	323	396
Strontium-90	New	Lower DL	Filtered	fCi/L	4.78	2.39	14	0.641	15.6	1.03	1.14
Sulfate	New	More data	Unfiltered	µg/L	27102	1537	28	11190	71212	47014	54950
Sulfide	New	More data	Filtered	µg/L	1.71	1.21	32	1.6	3.21	2.19	2.35
Technetium-99	Historical	No new	Unfiltered	pCi/L	0.447	1.62	5	0.271	0.752	0.83	0.988
Thallium	Historical	No new	Filtered	µg/L	1.14	1.35	4	0.883	1.73	1.67	1.87
Thorium	New	No Hist.	Filtered	µg/L	0.5	1	25	0.5	0.5	0.5	0.5
Tin	Historical	No new	Filtered	µg/L	15.9	1.27	12	11.8	31.3	21.6	23.6
Titanium	Historical	No new	Filtered	µg/L	30	1	7	30	30	30	30
Total carbon	New	No Hist.	Unfiltered	µg/L	30325	1174	32	20990	43175	37234	39462
Total dissolved solids	New	No Hist.	Unfiltered	µg/L	200919	1.22	30	140000	295000	258189	277190
Total inorganic carbon	New	More data	Unfiltered	µg/L	28722	1166	32	19550	39020	34955	36953
Total organic carbon	New	No Hist.	Unfiltered	µg/L	1293	1779	32	560	6720	2706	3336
Tritium	Historical	More data	Unfiltered	pCi/L	63.9	1.63	15	27.8	131	119	142
Uranium	New	More data	Filtered	µg/L	2.57	2.85	25	0.5	12.8	9.85	14.4
Uranium-234	Historical	No new	Unfiltered	pCi/L	0.75	1.1	2	0.7	0.803	0.849	0.88
Uranium-235	New	Lower DL	Filtered	fCi/L	23.1	3.34	17	1.55	114	0	0
Uranium-238	New	Lower DL	Filtered	fCi/L	721	1.89	17	150	2440	0	0
Vanadium	New	Lower DL	Filtered	µg/L	1.83	4.19	32	0.5	16.7	11.5	19.3

Table 6-1. Selected Summary Statistics for Groundwater Background (Page 4 of 4)

Analyte	Data Set	Reason for Selection	Sample Type	Units	Geo. Mean	Geo. Std. Dev.	No. of Samples	Minimum	Maximum	90th Percentile	95th Percentile
Zinc	New	Lower DL	Filtered	µg/L	1.27	9.22	32	0.05	1270	21.8	48.9
Zirconium	Historical	No new	Filtered	µg/L	25	1	7	25	25	25	25

Shading indicates that > 50% of the data below detection limit.

* Assume value of zero, as this is a Hanford Site contaminant not found in fallout.

DL = Detection Limit

µg/L = micrograms per liter

pCi/L = picocuries per liter

fCi/L = femtocuries per liter (10^{-3} pCi/L)

aCi/L = attocuries per liter (10^{-6} pCi/L)

mS/cm = millisiemens per centimeter

Table 6-2. Comparison of Groundwater Background Values to Regulatory Standards

Analyte	Units	Historical Data		New Data		Regulatory Standards			
		90th Percentile	Maximum	90th Percentile	Maximum	MCL	MTCA B	State GWQ	AWQC
Antimony	µg/L	55	53.9	nd	nd	6	6.4		
Arsenic	µg/L	7.1	8.2	7.8	8.8	50	0.05		0.018 ^b
Beryllium	µg/L	2.3	2.5	0.9	0.5	4	0.0203		5.3 ^b
Chromium	µg/L	6.6	6.0	2.4	4.4	100	80	50	11 ^b
Lead	µg/L	2.4	2.2	0.92	0.5		5 ^a	50	1.78 ^c
Mercury	µg/L	0.12	0.15	0.003	0.012	2	4.8	2	0.012 ^c
Radium-226	pCi/L	nd	nd	1.98	0.094			3	
Selenium	µg/L	6.0	5.1	12.0	11	50	80	10	5 ^c
Thallium	µg/L	1.7	1.7	nd	nd	2	1.12		

Values that are shaded exceed one or more groundwater regulatory limits.

^a No *Model Toxics Control Act* (MTCA) Method B value; use MTCA Method A.

^b Federal Ambient Water Quality Criteria (AWQC) (40 CFR 131)

^c State Ambient Water Quality Criteria (AWQC)(WAC 173-201A-040)

GWQ = Washington State Groundwater quality Standards (WAC 173-200-040)

MCL = Safe Drinking Water Act Maximum Contaminant Level (40 CFR 141)

MTCA = MTCA Method B groundwater cleanup standard (WAC 173-340-7209(b) in Ecology publication #94-145, updated January 1996)

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APPENDIX A
CHEMICAL ANALYSES OF NEW GROUNDWATER SAMPLES

Yucca Valley Groundwater
Monitoring Station

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Table A-1. Chemical Analyses of New
Groundwater Samples (Page 1 of 4)

HEIS No.	Well Number	Date Sampled	Filtred?	Alkalinity mg/L	Ammonia mg/L	Bromide mg/L	Chloride mg/L	Cyanide mg/L	δ18O ppt	δ3H ppt	DO mg/L	EC mS/cm	Eh mv	Fluoride mg/L	Mercury mg/L	Nitrate mg/L	Nitrite mg/L	Oxalate mg/L	pH	Phosphate mg/L	Sulfate mg/L	Sulfide ug/L	TC mg/L	TDS mg/L	Temp. deg. C	TIC mg/L	TOC mg/L	Aluminum ug/L
BOBX53	199-H4-45	6/6/94	UF		<0.01	<0.10	5.401		-16.64	-138.9	7530	241	505	0.136	0.00053	7.745	0.07	<0.32	7.72	<0.28	30.5	<6.4	22.64	155000	19.26	22.13	0.7	<10
BOBX54	199-H4-45	6/6/94	F		<0.01	<0.10	5.55		-16.9	-137.7				0.143	0.00038	7.653	<0.07	<0.32		<0.28	30.7	<6.4	23			21.83	1.31	<10
BO9205	699-11-45A	8/30/93	UF	120	<0.06	0.067	4.631	<0.01	-16.9		2530	270	313	0.246	0.00028	7.731	<0.02	<0.19	7.74	<0.13	20.5	<3.2	30.13	173000	21.42	29.37	1.15	<1
BO9206	699-11-45A	8/30/93	F		<0.06	0.258	4.956	<0.01						0.238	<1.0E-04	7.61	0.122	<0.19		<0.13	20.4	<3.2	36.56			28.76	7.61	<1
BO7DL3	699-14-38	9/29/93	F	140	<0.06	0.259	4.808	<0.01	-16.66		2770	292	475	0.308	0.00265	5.81	<0.11	<0.56	7.71	<0.23	23.8	<3.2	33.82	187000	20.75	31.78	1.85	368
BO7DQ6	699-14-38	9/29/93	UF		<0.06	<0.14	4.369	<0.01						0.307	<1.0E-04	5.755	<0.11	<0.56		<0.23	23.6	<3.2	42.62			30.65	9.59	<1
BOBX08	699-14-38	5/20/94	UF	140	<0.01	<0.10	4.355		-16.55	-139.4	1920	285	326	0.26	0.00095	4.918	<0.07	<0.32	7.59	<0.28	23.6	<3.2	32.16	183000	18.66	31.12	0.45	<10
BOBX09	699-14-38	5/20/94	F		<0.01	<0.10	6.02		-16.78	-134.8				0.357	0.0005	6.513	<0.07	<0.32		<0.28	31.1	<3.2	32.59			31	0.82	<10
BO9213	699-15-15B	8/18/93	UF	120	<0.06	0.053	6.277	<0.01	-16		4250	425	288	0.281		24.169	<0.02	<0.19	7.77	<0.13	86.7	<3.2	29.32	272000	20.35	28.48	0.88	<1
BO9214	699-15-15B	8/18/93	F		<0.06	0.15	6.304	<0.01	-15.72					0.281		23.901	<0.02	<0.19		<0.13	86.2	<3.2	30.91			28.71	1.92	<1
BO7DM6	699-15-15B	9/8/93	UF	120	<0.06	<0.06	6.639	<0.01	-16.16		4870	424	366	0.301	0.00213	24.32	<0.08	<0.21	7.73	<0.10	86.5	<3.2	28.91		20.04	28.3	0.89	<1
BO7DM7	699-15-15B	9/8/93	F		<0.06	0.164	6.787	<0.01	-16.16					0.311	<1.0E-04	23.77	<0.08	<0.21		<0.10	86.1	<3.2	30.13			27.87	2.06	<1
BOBX13	699-15-15B	5/24/94	UF	120	<0.01	<0.10	6.621		-15.53	-139.6	4070	423	367	0.274	0.00035	23.999	<0.07	<0.32	7.59	<0.28	96.3	<3.2	28.71	270000	19.83	27.51	0.72	<10
BOBX14	699-15-15B	5/24/94	F		<0.01	0.111	7.043		-16.24	-130.8				0.267	0.00059	25.933	<0.07	<0.32		<0.28	101.9	<3.2	29.3			27.48	0.83	<10
BOBX68	699-15-15B	5/25/94	UF	<2.7	<0.01	<0.10	<0.18		-17.62	-137.4				0.019	0.0011	0.209	<0.07	<0.32		<0.28	<0.21	<3.2	1.04			0.56	0.51	<10
BOBX69	699-15-15B	5/25/94	F		<0.01	<0.10	<0.18		-17.62	-136.5				0.023	0.00075	0.11	<0.07	<0.32		<0.28	<0.21	<3.2	1.16			0.52	0.76	<10
BO9452	699-15-15B	12/20/94	UF	120	<0.01	0.05	6.64	<0.14	-15.16	-132.5				0.28		23.75	<0.02	<0.15		<0.11	86.5	<3.2	28.82			28.21	0.6	1.96
BO9453	699-15-15B	12/20/94	F		<0.01	0.12	6.51	<0.14	-15.41	-134.2				0.27		23.76	<0.02	<0.15		<0.11	85.8	<3.2	25.62			25.07	0.68	0.49
BO91Y1	699-19-43	8/11/93	UF		<0.06	0.037	6.457	<0.01			5760	360	254	0.34		13.264	<0.02	<0.19	7.78	<0.13	57.6	<3.2	31.4	231000	19.68	30.58	1.04	<1
BO91Y2	699-19-43	8/11/93	F		<0.06	0.26	6.961	<0.01						0.316		12.99	0.041	<0.19		<0.13	56.3	<3.2	31.5			29.46	1.87	<1
BO7DM0	699-19-58	9/21/93	UF	140	<0.06	<0.14	3.631	<0.01	-17.27		380	291	91	0.305	0.00023	<0.17	<0.11	<0.56	7.49	<0.23	22.9	<6.4	35.6	186000	20.44	34.73	0.74	<1
BO7DM1	699-19-58	9/21/93	F		<0.06	<0.14	3.874	<0.01	-17.01					0.357	0.00046	<0.17	<0.11	<0.56		<0.23	22.8	<6.4	37			34.57	1.9	<1
BO94B8	699-19-88	9/29/93	UF	120	<0.06	<0.06	4.19	<0.01	-17.01		6160	239	519	0.282	<1.0E-04	1.665	<0.08	<0.21	7.59	0.124	12.9	<3.2	29.03	153000	18.51	28.02	0.7	<1
BO94B9	699-19-88	9/29/93	F		<0.06	0.068	4.076	<0.01	-17.68					0.294	<1.0E-04	1.684	<0.08	<0.21		<0.10	12.8	<3.2	47.64			28.24	17.38	<1
BO7DQ9	699-2-33A	8/27/93	UF	130	<0.06	<0.03	2.907	<0.01	-17.5		660	315	311	0.176	0.00238	2.054	<0.02	<0.19	7.41	<0.13	17.8	<3.2	33	202000	20.19	32.45	1.11	<1
BO7DR0	699-2-33A	8/27/93	F		<0.06	0.199	5.617	<0.01	-16.78					0.241	0.00253	3.907	<0.02	<0.19		<0.13	37.4	<3.2	35.58			32.44	2.92	<1
BO7DR1	699-24-46	8/25/93	UF	130	0.882	0.038	3.515	<0.01	-17.01		2400	301	305	0.313	0.00295	7.373	<0.02	<0.19	7.78	<0.13	25.7	<3.2	33.58	193000	20.98	33.41	0.93	<1
BO7DR2	699-24-46	8/25/93	F		0.716	0.159	3.691	<0.01	-17.21					0.328	0.00658	7.679	<0.02	<0.19		<0.13	25.9	<3.2	39.77			33.02	6.71	<1
BO9221	699-4-E6	8/19/93	UF	120	<0.06	0.106	14.238	<0.01			6600	377	274	0.281		19.227	<0.02	<0.19	7.78	<0.13	53.1	<3.2	29.84	241000	19.04	28.37	1.06	<1
BO9222	699-4-E6	8/19/93	F		<0.06	0.32	14.314	<0.01	-16.05					0.267		19.025	<0.02	<0.19		<0.13	53.0	<3.2	31.26			28.2	2.49	<1
BO7DM4	699-40-33A	9/24/93	UF	170	<0.06	<0.14	2.065	<0.01	-19.49		320	287	129	0.369	0.00038	<0.17	<0.11	<0.56	8.1	<0.23	2.8	<3.2	39.8	183000	18.81	39.62	0.74	<1
BO7DM5	699-40-33A	9/24/93	F		<0.06	<0.14	3.522	<0.01	-19.51					0.762	<1.0E-04	<0.17	<0.11	<0.56		<0.23	1.2	<3.2	40.26			39.5	1.25	<1
BO9476	699-43-88	9/28/93	UF	100	<0.06	<0.14	11.915	<0.01	-17.55		8190	322	341	0.171	0.00016	26.451	<0.11	<0.56	7.75	<0.23	36.3	<3.2	31.83	206000	20.51	24.11	6.72	57.4
BO9477	699-43-88	9/28/93	F		<0.06	0.21	12.47	<0.01	-17					0.17	0.00012	27.524	<0.11	<0.56		<0.23	37.1	<3.2	36.88			24.09	11.26	3.4
BO94G0	699-47-46A	9/16/93	UF	80	<0.06	0.136	21.508	<0.01	-16.24		8640	426	329	0.394	<1.0E-04	15.278	<0.11	<0.56	7.68	<0.23	103.3	<3.2	20.99	273000	18.5	19.55	1.37	<1
BO94G1	699-47-46A	9/16/93	F		<0.06	0.39	21.739	<0.01	-17.44					0.402	<1.0E-04	15.087	<0.11	<0.56		<0.23	103.4	<3.2	22.11			19.47	2.18	<1
BO9229	699-48-18	8/20/93	UF	130	<0.06	0.052	8.11	<0.01			7540	321	264	0.169		3.964	<0.02	<0.19	7.75	<0.13	39.1	<3.2	32.16	206000	18.5	30.84	0.96	<1
BO9230	699-48-18	8/20/93	F		<0.06	0.156	8.103	<0.01	-15.9					0.164		3.889	<0.02	<0.19		<0.13	39.2	<3.2	35.56			31.63	2.85	<1
BO9492	699-49-100A	10/14/93	UF	140	<0.06	<0.06	4.599	<0.01	-19.77					0.683	0.00101	<0.07	<0.08	<0.21		<0.10	0.6	<3.2	35.59			33.67	1.05	2.4
BO9493	699-49-100A	10/14/93	F		<0.06	<0.06	2.32	<0.01	-18.99					0.348	<1.0E-04	<0.07	<0.08	<0.21		<0.10	0.6	<3.2	35.64			33.7	1	<1
BO9237	699-50-28B	9/8/93	UF	120	<0.06	<0.14	8.537	<0.01	-18.09		7870	301	376	0.45	0.00064	5.587	<0.11	<0.56	7.69	<0.23	28.8	<3.2	30.88		22.12	30.27	1.01	<1
BO9238	699-50-28B	9/8/93	F		<0.06	0.156	8.754	<0.01	-14.99					0.434	<1.0E-04	5.516	<0.11	<0.56		<0.23	29.2	<3.2	31.94			30.27	1.93	<1
BO9245	699-50-85	8/23/93	UF	110	<0.06	0.104	9.405	<0.01			5560	313	306	0.159		26.81	<0.02	<0.19	7.73	<0.13	22.5	<3.2	28.91	200000	22.82	28.05	1.25	<1
BO9246	699-50-85	8/23/93	F		<0.06	0.924	10.282	<0.01	-17.35					0.177		26.428	<0.02	<0.19		<0.13	22.6	<3.2	28.86			27.75	1.72	<1
BO7DM8	699-51-75	9/28/93	UF	110	<0.06	<0.14	2.697	<0.01	-18.73		8210	251	355	0.276	0.00016	4.542	<0.11	<0.56	7.89	<0.23	23.2	<3.2	27.51	160000	19.73	28.42	0.85	104
BO7DM9	699-51-75	9/28/93	F		<0.																							

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Table A-1. Chemical Analyses of New
Groundwater Samples (Page 2 of 4)

	Americium	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iodine	Iron	Lead	Lithium	Magnesium	Manganese	Molybdenum	Nickel	Plutonium	Selenium	Sodium	Strontium	Technetium	Thorium	Uranium	Vanadium	Zinc	
HEIS No.	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	
BOBX53		2.09	17.5	<0.1	<0.1		6.31	<0.1	<0.1		<100	<0.1	1.27		<0.1		<0.1		<0.1		173				2.90	1.40	
BOBX54		2.48	16.5	<0.1	<0.1		4.42	<0.1	0.1		<100	<0.1	1.20		<0.1		<0.1		<0.1		159				2.65	0.27	
BO9205	<0.01	2.93	75.5	<1	<1	33100	<1	<1	<1	<0.5	<100	<1	11.00	12400	54.3	<1	1.76	<0.01	7	10600	182	<0.01	<1	3.87	<1	296.00	
BO9206	<0.01	2.1	78.6	<1	<1	34600	<1	<1	<1	<0.5	<100	<1	11.00	12900	57.2	<1	1.1	<0.01	4.4	11100	190	<0.01	<1	4.19	<1	226.00	
BO7DL3	<0.01	4.29	61.4	<1	<1	34600	3.1	<1	<1	<0.5	700	<1		12600	26.5	7.73	3.01	<0.001	8.6	17500	179	<0.01	<1	1.93	9.64	4.21	
BO7DQ6	<0.01	4.9	52.2	<1	<1	33400	2.24	<1	<1	<0.5	60	<1		12600	1.62	7.36	<1	<0.001	<5	17700	169	<0.01	<1	2.19	9.13	<1	
BOBX08		3.96	43.3	<0.1	<0.1		2.63	<0.1	0.16		<100	<0.1	4.13		0.18		0.48		<0.1		149				5.60	0.60	
BOBX09		4.58	43.7	<0.1	<0.1		2.99	<0.1	<0.1		<100	<0.1	4.50		0.38		0.22		<0.1		168				6.34	0.66	
BO9213	<0.01	<1	48.2	<1	<1	47000	1.98	<1	<1	<0.5	<100	<1	8.26	12400	<1	<1	<1	<0.01	<1	24600	218	<0.01	<1	8.04	<1	13.10	
BO9214	<0.01	<1	40.3	<1	<1	40000	<1	<1	<1	<0.5	<100	<1	6.32	10200	<1	<1	<1	<0.01	<1	19900	183	<0.01	<1	6.97	3.63	<1	
BO7DM6	<0.01	8.5	96.1	<1	<1	57400	<1	<1	<1	<0.5	<100	4.58	11.00	13100	<1	4.85	<1	<1	<0.01	21	4330	279	<0.01	<1	18.70	<1	32.50
BO7DM7	<0.01	8.96	94.8	<1	<1	58300	<1	<1	<1	<0.5	<100	<1	16.90	12600	4.57	<1	<1	<0.01	27	4070	285	<0.01	<1	18.70	<1	29.60	
BOBX13		6.89	46.8	<0.1	<0.1		4.2	<0.1	<0.1		<100	<0.1	4.81		1.84		1.33		13.86		359				10.39	70.48	
BOBX14		6.58	47.1	<0.1	<0.1		3.49	<0.1	<0.1		<100	<0.1	4.39		1.62		1.17		14.2		289				9.21	59.03	
BOBX68		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1		<100	<0.1	<0.1		<0.1		<0.1		0.81		<0.1				<0.1	<0.1	
BOBX69		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1		<100	<0.1	<0.1		<0.1		<0.1		1.11		<0.1				<0.1	<0.1	
BO9452		7.35	40.4	<0.1	<0.1	52842	3.18	<0.1	<0.1		8.86	<0.1	5.28	10134	1.8		1.9		15.06	21568	269				12.68	47.71	
BO9453		6.99	41.0	<0.1	<0.1	52054	2.48	<0.1	0.17		<0.1	<0.1	4.42	10012	1.78		1.11		15.03	22174	269				11.43	35.85	
BO91Y1	<0.01	<1	56.6	<1	<1	41000	1.76	<1	<1	<0.5	<100	<1	7.10	11500	<1	<1	<1	<0.01	<1	19600	187	<0.01	<1	8.04	<1	31.50	
BO91Y2	<0.01	<1	53.2	<1	<1	40200	<1	<1	<1	<0.5	<100	<1	7.50	11200	<1	<1	<1	<0.01	<1	18900	179	<0.01	<1	7.56	<1	<1	
BO7DM0	<0.01	<1	57.7	<1	<1	31700	<1	<1	<1	<0.5	<100	<1	10.40	13900	91.8	<1	<1	<0.01	3.74	11600	133	<0.01	<1	<1	<1	<1	
BO7DM1	<0.01	<1	56.8	<1	<1	31900	<1	<1	<1	<0.5	<100	<1	11.50	13500	94.4	<1	<1	<0.01	4.5	11600	135	<0.01	<1	<1	<1	<1	
BO94B8	<0.01	<1	10.6	<1	<1	26800	1.87	<1	<1	<0.5	71.8	<1		10400	1.1	2.62	3.17	<0.001	<5	12100	106	<0.01	<1	<1	19.10	13.20	
BO94B9	<0.01	1.72	10.8	<1	<1	26600	<1	<1	<1	<0.5	55	<1		9860	<1	2.53	3.55	<0.001	7.55	11400	109	<0.01	<1	<1	17.90	<1	
BO7DQ9	<0.01	<1	29.1	<1	<1	38800	<1	<1	<1	<0.5	<100	<1	8.36	13000	<1	<1	<1	<0.01	<1	12100	157	<0.01	<1	4.46	<1	<1	
BO7DR0	<0.01	<1	24.3	<1	<1	31800	<1	<1	<1	<0.5	<100	<1	7.30	11100	<1	<1	<1	<0.01	<1	10100	129	<0.01	<1	3.82	<1	<1	
BO7DR1	<0.01	<1	80.2	<1	<1	29200	<1	<1	<1	<0.5	<100	<1	9.30	13200	14.857862	<1	<1	<0.01	<1	16100	128	<0.01	<1	1.89	<1	<1	
BO7DR2	<0.01	<1	81.3	<1	<1	30100	<1	<1	<1	<0.5	<100	<1	12.10	12800	13.719744	<1	<1	<0.01	<1	15900	132	<0.01	<1	1.85	<1	<1	
BO9221	<0.01	<1	39.0	<1	<1	36800	<1	<1	<1	<0.5	<100	<1	8.99	13400	<1	<1	<1	<0.01	4.4	18100	199	<0.01	<1	5.78	<1	<1	
BO9222	<0.01	<1	41.0	<1	<1	37300	<1	<1	<1	<0.5	<100	<1	6.80	14700	<1	<1	<1	<0.01	<1	19200	207	<0.01	<1	6.12	<1	<1	
BO7DM4	<0.01	7.6	115.0	<1	<1	13300	3.05	<1	<1	<0.5	<100	<1	12.20	3320	36.2	3.47	<1	<0.01	<1	11800	103	<0.01	<1	2.04	2.41	<1	
BO7DM5	<0.01	7.1	106.0	<1	<1	12600	2.42	<1	<1	<0.5	<100	<1	12.20	3130	27.7	3.34	<1	<0.01	<1	15100	100	<0.01	<1	2.17	<1	<1	
BO9476	<0.01	1.16	57.6	<1	<1	43200	7.24	<1	<1	<0.5	2380	<1		10800	25.1	10.7	4.2	<0.001	6.51	13900	152	<0.01	<1	<1	13.90	16.00	
BO9477	<0.01	<1	46.0	<1	<1	38400	1.44	<1	<1	<0.5	48.9	<1		11800	17.6	11.6	2.08	<0.001	<5	14800	127	<0.01	<1	<1	10.70	<1	
BO94G0	<0.01	4.78	90.8	<1	<1	41200	<1	<1	<1	<0.5	<100	<1	16.10	14800	3.91	1.82	3.67	<0.01	4.52	3980	287	<0.01	<1	7.19	<1	<1	
BO94G1	<0.01	4.56	94.1	<1	<1	43500	<1	<1	<1	<0.5	<100	<1	18.60	15800	4.74	2.04	2.07	<0.01	8.85	4000	309	<0.01	<1	7.49	<1	<1	
BO9229	<0.01	<1	29.2	<1	<1	31800	1.71	<1	<1	<0.5	<100	<1	7.29	11700	<1	<1	<1	<0.01	<1	12800	200	<0.01	<1	3.54	<1	<1	
BO9230	<0.01	<1	32.9	<1	<1	37500	1.87	<1	<1	<0.5	<100	<1	7.61	13700	<1	<1	<1	<0.01	<1	15000	234	<0.01	<1	4.47	<1	<1	
BO9492	<0.01	<1	50.0	<1	<1	14800	<1	<1	<1	<0.5	163	<1		8560	48.8	2.47	<1	<0.001	<5	35600	52	<0.01	<1	<1	<1	5.06	
BO9493	<0.01	<1	46.5	<1	<1	14000	<1	<1	<1	<0.5	164	<1		8180	47.2	1.4	<1	<0.001	<5	33400	53	<0.01	<1	<1	<1	<1	
BO9237	<0.01	3.32	76.2	<1	<1	34400	<1	<1	<1	<0.5	<100	6.98	19.00	12800	60.6	3.39	4.7	<0.01	11	3920	277	<0.01	<1	11.20	<1	203.00	
BO9238	<0.01	2.28	75.4	<1	<1	33600	<1	<1	<1	<0.5	<100	<1	15.60	12000	60.1	4.17	2.56	<0.01	6.8	3990	279	<0.01	<1	10.80	<1	150.00	
BO9245	<0.01	<1	29.6	<1	<1	33600	<1	<1	<1	<0.5	<100	<1	3.62	14500	3.5199139	<1	<1	<0.01	<1	9720	114	<0.01	<1	<1	<1	<1	
BO9246	<0.01	<1	27.4	<1	<1	32800	<1	<1	<1	<0.5	<100	<1	4.28	14200	<1	<1	<1	<0.01	<1	9570	107	<0.01	<1	<1	<1	<1	
BO7DM8	<0.01	1.16	32.4	<1	<1	30800	3.83	<1	<1	<0.5	3770	<1		10900	35.3	3.47	1.25	<0.001	9.12	8640	187	<0.01	<1	1.06	20.50	16.00	
BO7DM9	<0.01	1.94	29.3	<1	<1	30000	2.79	<1	<1	<0.5	13	<1		10300	20.5	4.84	<1	<0.001	<5	8360	183	<0.01	<1	<1	16.70	<1	
BO94D4	<0.01	5.12	7.9	<1	<1	2380	<1	<1	<1	<0.5	55	3.78		<10	<1	424	<1	<0.001	<5	17300	<1	<0.01	<1	<1	<1	<1	
BO94D5	<0.01	7.9	7.6	<1	<1	2500	<1	<1	<1	<0.5	40.5	2.6		35.7	<1	437	<1	<0.001	<5	13900	2	<0.01	<1	<1	<1	<1	
BO9261	<0.01	3.2	3.6	<1	<1	33300	<1	<1	<1	<0.5	<100	<1	5.00	11100	4.99	<1	2.92	<0.01	5.9	5170	148	<0.01	<1	4.02	<1	<1	
BO9262	<0.01	4.85	8.2	<1	<1	37400	<1	<1	<1	<0.5	<100	<1	9.30	13300	2.78	<1	3.36	<0.01	7.4	6170	163	<0.01	<1	4.39</			

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Table A-1. Chemical Analyses of New
Groundwater Samples (Page 3 of 4)

HEIS No.	Well Number	Date Sampled	Filtered?	Alkalinity mg/L	Ammonia mg/L	Bromide mg/L	Chloride mg/L	Cyanide mg/L	δ18O ppt	δ3H ppt	DO mg/L	EC mS/cm	Eh mv	Fluoride mg/L	Mercury mg/L	Nitrate mg/L	Nitrite mg/L	Oxalate mg/L	pH	Phosphate mg/L	Sulfate mg/L	Sulfide ug/L	TC mg/L	TDS mg/L	Temp. deg. C	TIC mg/L	TOC mg/L	Aluminum ug/L
BOBX23	699-57-25A	5/9/94	UF	130	<0.01	0.111	7.215		-18.16	-131.7	7420	286	282	0.397	0.0015	3.432	<0.07	<0.32	7.73	<0.28	22.4	<3.2	30.64	183000	20.16	30.18	0.77	<10
BOBX24	699-57-25A	5/9/94	F		<0.01				-18.39	-140.5					0.00788							<3.2	66.18			29.38	37.22	<10
BO9269	699-57-83A	9/14/93	UF	120	<0.06	<0.14	9.436	<0.01	-18.37		6810	274	328	0.218	<1.0E-04	7.006	<0.11	<0.56	7.93	<0.23	23.4	<3.2	30.13	175000	17.78	28.58	1.96	<1
BO9270	699-57-83A	9/14/93	F		<0.06	0.26	9.81	<0.01	-18.31					0.204	<1.0E-04	7.096	<0.11	<0.56		<0.23	23.8	<3.2	32.46			28.29	3.95	<1
BO9277	699-62-31	8/25/93	UF	120	0.079	0.037	9.003	<0.01			5200	376	222	0.296		38.901	<0.02	<0.19	7.39	<0.13	36.4	<3.2	29.8	241000	18.97	29.52	1.42	<1
BO9278	699-62-31	8/25/93	F		0.076	0.158	9.222	<0.01	-18.14					0.316		38.543	<0.02	<0.19		<0.13	37.0	<3.2	30.2			29.58	1.47	<1
BO7DR3	699-63-90	8/28/93	UF	120	<0.06	0.084	8.685	<0.01	-17.31		7500	295	357	0.227	0.00195	5.736	<0.02	<0.19	7.68	<0.13	29.9	<3.2	30.29	189000	18.64	29.43	1.11	<1
BO7DR4	699-63-90	8/28/93	F		0.23	0.162	9.028	<0.01	-17.94					0.217	0.00325	5.923	<0.02	<0.19		<0.13	29.9	<3.2	31.26			29.34	2.1	<1
BO7DL5	699-66-103	9/10/93	UF	100	0.12	<0.14	2.812	<0.01	-18.16		7050	221	358	0.133	0.00086	2.821	<0.11	<0.56	7.92	<0.23	17.5	<3.2	25.56	141000	14.78	24.69	1	<1
BO7DL9	699-66-103	9/10/93	F		<0.06	<0.14	2.883	<0.01	-18.51					0.123	0.00859	2.416	<0.11	<0.56		<0.23	17.5	<3.2	25.8			24.72	1.2	<1
BO9428	699-67-86	9/15/93	UF	120	<0.06	<0.14	5.316	<0.01	-18.66		7410	294	325	0.306	<1.0E-04	2.612	<0.11	<0.56	7.75	<0.23	34.0	<3.2	30.78	188000	23.69	29.13	1.54	<1
BO9429	699-67-86	9/15/93	F		<0.06	0.155	5.33	<0.01	-18.58					0.337	<1.0E-04	2.588	<0.11	<0.56		<0.23	34.1	<3.2	30.26			29.03	1.36	<1
BOBX58	699-73-61	5/18/94	UF	110	<0.01	<0.10	7.953		-17.61	-141.3	9210	306	386	0.286	0.00071	10.271	<0.07	<0.32	7.69	<0.28	54.8	<3.2	27.2	196000	18.52	25.96	0.64	<10
BOBX59	699-73-61	5/18/94	F		<0.01	0.171	6.482		-18.13	-138.7				2.52	0.0005	8.671	<0.07	<0.32		<0.28	46.0	<3.2	27.37			25.6	0.92	<10
BOBX28	699-73-61	5/18/94	UF	110	<0.01	<0.10	7.535		-18.22	-138.7	9210	306	386	0.268	0.0012	9.865	<0.07	<0.32	7.69	<0.28	52.2	<3.2	27.02	196000	18.52	26.26	0.38	<10
BOBX29	699-73-61	5/18/94	F		<0.01	<0.10	7.334		-18.27	-139.4				0.256	0.00072	10.065	<0.07	<0.32		<0.28	52.6	<3.2	26.93			25.94	0.63	<10
BOBX33	699-78-62	5/19/94	UF	110	<0.01	<0.10	8.719		-17.96	-137.7	8620	335	405	0.313	0.00062	8.576	<0.07	<0.32	7.67	<0.28	64.9	<3.2	26.84	214000	16.91	26.14	0.66	<10
BOBX34	699-78-62	5/19/94	F		<0.01	0.12	9.913		-17.53	-142.7				0.374	0.00036	9.702	<0.07	<0.32		<0.28	73.5	<3.2	27.53			25.89	1	<10
BOBX38	699-90-45	5/23/94	UF	110	0.109	<0.10	4.697		-18.09	-145	5960	300	146	0.395	0.00106	5.858	0.629	<0.32	6.77	<0.28	46.0	<3.2	28.55	191000	17.69	26.88	1.2	<10
BOBX39	699-90-45	5/23/94	F		0.148	<0.10	4.105		-18.66	-140.9				0.342	0.00074	5.073	0.098	<0.32		<0.28	41.4	<3.2	28.85			26.35	1.5	<10
BOBX43	699-91-46	5/13/94	UF	120	<0.01	<0.40	3.943		-17.86	-147.1	8040	290	326	0.427	0.00062	7.035	<0.07	<0.32	7.64	<0.28	30.7	<3.2	29.62	186000	16.34	28.22	0.65	<10
BOBX44	699-91-46	5/13/94	F		<0.01	0.11	4.569		-18.95	-143.4				0.5	0.00044	8.117	<0.07	<0.32		<0.28	35.3	<3.2	35.56			27.71	6.01	<10
BOBX48	699-93-48	5/13/94	UF	100	<0.01	<0.10	6.263		-18.33	-144.6	9250	269	339	0.433	0.00075	5.787	<0.07	<0.32	7.65	0.293	40.9	<3.2	24.46	172000	16.74	23.38	0.56	<10
BOBX49	699-93-48	5/13/94	F		<0.01	0.106	6.413		-18.12	-141.1				0.459	0.00053	5.906	<0.07	<0.32		<0.28	42.2	<3.2	25.43			23.38	1.29	<10
BO7DL4	699-S19-11	8/31/93	UF	100	<0.06	0.069	9.632	<0.01	-14.62		8670	296	348	0.25	0.01018	13.4	<0.02	<0.19	7.84	<0.13	38.2	<3.2	25.49	190000	18.68	24.55	1.06	<1
BO7DL8	699-S19-11	8/31/93	F		<0.06	0.173	9.795	<0.01	-14.76					0.238	<1.0E-04	13.084	<0.02	<0.19		<0.13	38.2	<3.2	25.65			24.5	1.29	<1
BOBWV3	699-S19-11	6/15/94	UF	110	<0.01	<0.10	9.088		-15	-120.8	8790	291	539	0.231	0.00052	10.33	<0.07	<0.32	7.6	<0.28	34.7	<6.4	25.52	186000	18.13	24.15	1	
BOBWV4	699-S19-11	6/15/94	F		<0.01	0.124	8.843		-14.88	-114.9				0.22	0.00054	10.069	<0.07	<0.32		<0.28	33.4	<6.4	26.09			23.68	1.8	
BOBWV8	699-S29-E12	5/17/94	UF	150	<0.01	<0.10	13.099		-14.79	-121.8	8950	396	444	0.235	0.00046	26.042	<0.07	<0.32	7.42	<0.28	39.6	<3.2	36.34	254000	17.21	34.63	1.27	<10
BOBWV9	699-S29-E12	5/17/94	F		<0.01	0.119	16.2		-14.34	-117.2				0.291	0.00046	33.241	<0.07	<0.32		<0.28	48.1	<3.2	41.14			34	6.2	<10
BO91Y9	699-S3-25	8/13/93	F		<0.06	0.237	23.795	<0.01	-16.82					0.411		2.513	<0.02	<0.19		<0.13	107.9	<3.2						<1
BO91Z0	699-S3-25	8/13/93	UF		<0.06	0.086	23.745	<0.01	-16.9					0.493		2.819	<0.02	<0.19		<0.13	108.8	<3.2	35.91			34.5	1.18	<1
BO7DM2	699-S31-1	9/15/93	UF	90	0.21	<0.14	5.219	<0.01	-18.51		6530	219	312	0.156	0.00037	4.941	<0.11	<0.56	8.02	<0.23	16.7	<3.2	23.14	140000	18.21	22.72	1.04	<1
BO7DM3	699-S31-1	9/15/93	F		0.32	<0.14	5.263	<0.01	-15.53					0.162	<1.0E-04	4.954	<0.11	<0.56		<0.23	16.6	<3.2	23.94			22.48	1.44	<1
BOBWV3	699-S31-E8A	5/31/94	UF	160	<0.01	<0.10	32.939		-14.89	-120	6430	462	510	0.217	0.00053	31.04	<0.07	<0.32	7.36	<0.28	24.6	<3.2	38.28	295000	16.49	36.01	1.3	<10
BOBWV4	699-S31-E8A	5/31/94	F		<0.01	0.345	39.553		-14.7	-111				0.242	0.0007	36.828	<0.07	<0.32		<0.28	29.6	<3.2	38.52			35.92	1.85	<10
BOBWV8	699-S34-E10	5/31/94	UF	190	<0.01	<0.10	17.458		-14.55	-123.4	7700	570	503	0.239	0.00071	61.921	<0.07	<0.32	7.39	<0.28	63.0	<3.2	46.47	364000	16.22	43.97	1.67	<10
BOBWV9	699-S34-E10	5/31/94	F		<0.01	0.377	16.935		-14.74	-122.5				0.229	0.00057	58.336	<0.07	<0.32		<0.28	59.4	<6.4	47.7			43.91	2.8	<10
BOBX63	699-S34-E10	5/31/94	UF	190	<0.01	0.14	19.4		-14.5	-114.3				0.274	0.00056	66.97	<0.07	<0.32		<0.28	68.0	<6.4	46.78			44.38	1.64	<10
BOBX64	699-S34-E10	5/31/94	F		<0.01	0.398	18.96		-13.85	-118.2				0.269	0.00059	64.458	<0.07	<0.32		<0.28	66.0	<6.4	46.47			44.13	1.86	<10
BOBWV3	699-S37-E11A	5/11/94	UF	150	<0.01	0.122	16.563		-15.67	-125.4	9440	381	303	0.243	0.00119	28.063	<0.07	<0.32	7.48	<0.28	41.3	<3.2	36.6	244000	17.08	34.99	1.31	<10
BOBWV4	699-S37-E11A	5/11/94	F		<0.01	<0.10	13.171		-15.17	-129.5				0.188	0.00051	21.484	<0.07	<0.32		<0.28	33.2	<3.2	39.05			34.63	2.98	<10
BOBWZ3	699-S38-12A	5/26/94	UF	130	<0.01	<0.10	6.115		-16.58	-134.1	8980	275	448	0.172	0.00085	7.163	<0.07	<0.32	7.5	<0.28	17.1	<6.42	31.2	176000	16.79	30	1.02	<10
BOBWZ4	699-S38-12A	5/26/94	F		<0.01	<0.10	6.958		-17.05	-136.4				0.198	0.00075	8.086	<0.07	<0.32		<0.28	19.6	<6.42	31.43			29.71	0.86	<10
BOBWV8	699-S38-E11	5/16/94	UF	160	<0.01	0.123	18.734		-15.32	-127.6	9110	480	405	0.222	0.00142	45.542	<0.07	<0.32	7.52	<0.28	50.2	<3.2	38.02	307000	16.39	36.08	1.8	<10
BOBWZ8	699-S41-E12	6/1/94	UF	240	<0.01	0.173	99.6		-15.24	-126.8																		

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Table A-1. Chemical Analyses of New
Groundwater Samples (Page 4 of 4)

	Americium	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iodine	Iron	Lead	Lithium	Magnesium	Manganese	Molybdenum	Nickel	Plutonium	Selenium	Sodium	Strontium	Technetium	Thorium	Uranium	Vanadium	Zinc
HEIS No.	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
BOBX23		13.07	15.9	<0.1	<0.1		1.86	<0.1	<0.1		<10	<0.1	3.68		0.88		0.3		<0.1		113				19.29	1.84
BOBX24		13.44	16.0	<0.1	<0.1		1.91	<0.1	<0.1		<10	<0.1	3.75		1.24		0.22		<0.1		114				19.72	<0.1
BO9269	<0.01	1.4	24.0	<1	<1	33400	<1	<1	<1	<0.5	<100	<1	5.30	14300	2.51	<1	1.44	<0.01	4.9	7010	157	<0.01	<1	3.86	<1	<1
BO9270	<0.01	<1	21.3	<1	<1	32600	<1	<1	<1	<0.5	<100	<1	2.61	13600	2.54	<1	2.5	<0.01	5.4	6580	160	<0.01	<1	3.84	<1	<1
BO9277	<0.01	<1	46.8	<1	<1	38700	<1	<1	<1	<0.5	<100	<1	8.00	12600	45.98435	<1	<1	<0.01	<1	27300	197	<0.01	<1	1.50	<1	1480.00
BO9278	<0.01	<1	47.9	<1	<1	38800	<1	<1	<1	<0.5	<100	<1	10.18	12600	42.728125	<1	<1	<0.01	<1	27300	203	<0.01	<1	1.24	<1	1270.00
BO7DR3	<0.01	<1	18.8	<1	<1	32300	<1	<1	<1	<0.5	<100	<1	5.80	14700	<1	<1	<1	<0.01	<1	11800	122	<0.01	<1	1.60	<1	<1
BO7DR4	<0.01	<1	17.1	<1	<1	30500	<1	<1	<1	<0.5	<100	<1	5.99	13900	<1	<1	<1	<0.01	<1	11200	113	<0.01	<1	1.38	<1	<1
BO7DL5	<0.01	<1	<1	<1	<1	3030	<1	<1	<1	<0.5	<100	<1	3.20	723	2	<1	<1	<0.01	3.5	930	12	<0.01	<1	<1	<1	<1
BO7DL9	<0.01	1.04	<1	<1	<1	3390	<1	<1	<1	<0.5	<100	<1	4.60	825	2.47	<1	<1	<0.01	5.7	1010	13	<0.01	<1	<1	<1	<1
BO9428	<0.01	2	13.9	<1	<1	32900	8.87	<1	<1	<0.5	<100	4.81	8.60	10800	5.29	<1	<1	<0.01	5.1	14900	135	<0.01	<1	2.22	<1	<1
BO9429	<0.01	2.65	13.8	<1	<1	33200	7.61	<1	<1	<0.5	<100	1.96	11.30	10900	1.96	<1	<1	<0.01	5	15200	137	<0.01	<1	2.34	<1	<1
BOBX58		2.56	22.7	<0.1	<0.1		6.37	<0.1	<0.1		<100	0.57	0.36		2.5		<0.1		1		191			5.20	116.00	
BOBX59		2.81	22.6	<0.1	<0.1		7.09	<0.1	<0.1		<100	2.62	0.37		5.07		<0.1		0.88		255			5.73	101.00	
BOBX28		2.44	23.1	<0.1	<0.1		5.6	<0.1	<0.1		<100	<0.1	3.86		2.34		<0.1		0.89		259			4.59	112.00	
BOBX29		2.53	22.2	<0.1	<0.1		7.08	<0.1	<0.1		<100	<0.1	4.03		4.23		<0.1		<0.1		207			5.67	106.00	
BOBX33		4.46	27.4	<0.1	<0.1		32.33	<0.1	<0.1		<100	<0.1	3.73		<0.1		<0.1		1.54		250			9.83	68.29	
BOBX34		3.87	29.2	<0.1	<0.1		28.38	<0.1	<0.1		<100	<0.1	3.53		<0.1		<0.1		1.28		294			8.74	73.44	
BOBX36		2.7	29.8	<0.1	<0.1		1.9	<0.1	<0.1		994	<0.1	4.27		49.39		0.62		<0.1		175			3.98	11.86	
BOBX39		3.2	28.9	<0.1	<0.1		1.76	<0.1	<0.1		1028	<0.1	4.18		83.96		0.51		<0.1		172			4.78	11.91	
BOBX43		8.85	27.9	<0.1	<0.1		10.04	<0.1	0.19		<10	0.11	3.83		0.86		1.28		<0.1		113			14.70	2.15	
BOBX44		9.18	28.6	<0.1	<0.1		9.33	<0.1	0.31		<10	<0.1	3.79		0.86		0.7		<0.1		169			14.40	<0.1	
BOBX48		6.05	38.1	<0.1	<0.1		13.39	<0.1	0.18		<10	<0.1	3.13		<0.1		0.88		<0.1		146			6.96	2.87	
BOBX49		5.72	37.2	<0.1	<0.1		12.05	<0.1	<0.1		<10	<0.1	3.01		0.2		0.54		<0.1		141			6.98	<0.1	
BO7DL4	<0.01	8	38.3	<1	<1	39200	<1	<1	<1	<0.5	<100	1.33	6.56	11800	3.23	<1	<1	<0.01	8.7	15300	176	<0.01	<1	6.29	<1	22.30
BO7DL8	<0.01	7.24	37.9	<1	<1	37200	<1	<1	<1	<0.5	<100	<1	7.32	11400	2.51	<1	<1	<0.01	3.02	15000	167	<0.01	<1	6.12	<1	<1
BOBWV3		6.65	20.7	<0.1	<0.1		3.39	<0.1	<0.1		<100	<0.41	1.39		<1.75		0.76		3.65					9.81		
BOBWV4		6.56	20.4	<0.1	<0.1		3.44	<0.1	<0.1		<100	<0.41	1.40		<1.75		0.41		4.24					9.75		
BOBWV6		4.99	48.6	<0.1	<0.1		2.26	<0.1	0.18		<10	<0.1	3.68		<0.1		0.44		0.39		451			7.29	5.59	
BOBWV9		5.22	49.5	<0.1	<0.1		2.45	<0.1	0.21		<10	<0.1	3.70		<0.1		0.27		0.26		402			7.46	5.69	
BO91Y9	<0.01	<1	77.2	<1	<1	58100	<1	<1	<1	<0.5	<100	<1	9.74	17300	64.182873	<1	<1	<0.01	<1	28500	236	<0.01	<1	5.39	<1	<1
BO91Z0	<0.01	<1	75.8	<1	<1	56800	<1	<1	<1	<0.5	<100	<1	10.77	17200	64.47617	<1	<1	<0.01	<1	28100	230	<0.01	<1	5.45	<1	<1
BO7DM2	<0.01	6.55	21.9	<1	<1	27800	<1	<1	<1	<0.5	<100	<1	3.00	7440	7.39	<1	<1	<0.01	8.1	7620	126	<0.01	<1	3.61	<1	<1
BO7DM3	<0.01	6.22	20.2	<1	<1	28900	<1	<1	<1	<0.5	<100	<1	3.96	7660	0.885	<1	<1	<0.01	8.4	8070	127	<0.01	<1	3.70	<1	<1
BOBWV3		7.66	45.9	<0.1	<0.1		3.23	0.1	<0.1		<100	<0.1	3.31		0.15		10.09		<0.1		248			9.41	1.06	
BOBWV4		7.72	46.5	<0.1	<0.1		2.94	<0.1	0.22		<100	<0.1	3.27		0.15		9.81		<0.1		298			9.02	0.87	
BOBWV8		5.74	62.1	<0.1	<0.1		4.63	0.41	0.36		<100	<0.1	3.59		0.33		2.97		<0.1		426			8.26	1.26	
BOBWV9		5.65	62.5	<0.1	<0.1		3.44	0.39	0.43		<100	<0.1	3.75		0.29		2.2		<0.1		635			8.20	0.98	
BOBX63		6.58	61.4	<0.1	<0.1		4.2	0.5	0.34		<100	<0.1	3.49		<0.1		0.93		<0.1		511			6.95	0.83	
BOBX64		6.75	60.9	<0.1	<0.1		3.02	0.48	0.4		<100	<0.1	3.45		<0.1		0.1		<0.1		562			7.17	0.77	
BOBWY3		6.68	40.3	<0.1	<0.1		3.5	<0.1	<0.1		<100	<0.1	3.07		<0.1		<0.1		<0.1		258			8.66	0.59	
BOBWY4		6.96	40.3	<0.1	<0.1		2.69	<0.1	0.19		<100	<0.1	2.85		<0.1		0.42		<0.1		190			7.73	1.14	
BOBWZ3		5.86	35.1	<0.1	<0.1		2.67	<0.1	<0.1		<100	<0.1	2.38		<0.1		0.77		<0.1		134			7.56	0.84	
BOBWZ4		5.55	33.6	<0.1	<0.1		2.64	<0.1	<0.1		<100	<0.1	2.46		<0.1		0.36		<0.1		137			7.93	1.08	
BOBWY8		8.41	38.9	<0.1	<0.1		2.51	0.21	0.32		<10	<0.1	2.85		<0.1		1.26		<0.1		467			10.38	1.14	
BOBWZ8		2.88	82.7	<0.1	<0.1		8.21	0.26	0.52		<100	<0.1	4.51		1.44		47.75		<0.1		437			6.62	1.81	
BOBWZ9		2.55	79.5	<0.1	<0.1		3.78	0.22	0.29		<100	<0.1	4.32		1.17		43.6		<0.1		468			6.33	1.76	
BOBX03		5.65	41.1	<0.1	<0.1		3.96	<0.1	0.22		<10	<0.1	2.74		0.32		1.52		<0.1		287			7.85	<0.1	
BOBX04		5.58	40.6	<0.1	<0.1		2.23	<0.1	0.22		<10	<0.1	2.47		0.33		1.32		<0.1		298			7.45	<0.1	
BO7F14	<0.01	6.62	48.6	<1	<1	34800	5.84	<1	<1	<0.5	<100	<1	4.20	8270	3.69	4.62	<1	<0.01	<1	18400	169	<0.01	<1	4.37	12.10	5.37
BO7F15	<0.01	6.5	53.5	<1	<1	37900	4.58	<1	<1	<0.5	<100	<1	3.38	9910	2.79	3.23	<1	<0.01	<1	20300	182	<0.01	<1	4.64	12.00	4.70
BO7F16	<0.01	6.37	51.2	<1	<1	36100	4.15	<1	<1	<0.5	<100	<1	3.76	8750	3.47	3.62	<1	<0.01	<1	19200	172	<0.01	<1	4.22	12.00	<1
BO7F17	<0.01	7.9	52.6	<1	<1	37500	4.24	<1	<1	<0.5	<100	<1	3.35	9310	3.04	3.63	<1	<0.01	<1	19100	173	<0.01	<1	4.33	11.30	<1
BOBX73		<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1		<100	<0.1	<0.1		<0.1		<0.1		0.27		0			<0.1	<0.1	
BOBX74		<0.1	<0.1	<0.1	<0.1		1.27	<0.1	<0.1		<100	<0.1	<0.1		<0.1		<0.1		<0.1		<0.1			<0.1	<	

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Table A-2. Radionuclide Analyses of New
Groundwater Samples (Page 1 of 4)

Well	Date	HEIS	F/UF	I-129	Gross Alpha		Gross Beta		Tritium	Duplicate	Pu-239+240			Pu-238	Am-241	Sr-90	K-40	Co-60						
				aCi/L	% Error	pCi/L	Counting Error	pCi/L	Counting Error		pCi/L	Counting Error	pCi/L	(1sigma)					fCi/L	Counting Error	fCi/L	Counting Error	fCi/L	Counting Error
199-H4-45	6/6/94	BOBX56	F	104.1	5.5	0.95	0.13	18.4	1.1	630	100													
699-11-45A	8/30/93	B09204	F	17.7	9.7	0.87	0.25	4.7	0.32	230	<			0.3	0.058	0.03	<	1	<	12.20	2.9	4.17	3.3	3.1
699-11-45A	8/30/93	B09203	UF	20.5	5.6	0.71	0.2	4.47	0.33	210	<	210	<											
699-14-38	9/29/93	B07DQ6	F			0.87	0.27	6.16	0.33	200	<			0.366	0.062	0.06	<	2	<	5.40	1.6	4.93	15.6	2.7
699-14-38	5/20/94	BOBX11	F	8.5	5.8	1.75	0.22	4.46	0.29	320	<													
699-14-38	9/29/93	B07DL3	UF	10.4	7	0.63	0.24	6.02	0.4	200	<													
699-15-15B	9/8/93	B07DM7	F			2.83	0.38	10.39	0.62	300	<			0.531	0.07	0.08	<	2	<	6.90	1.8	2.03	21	2.5
699-15-15B	8/18/93	B09212	F	28.2	9.2	2.23	0.37	8.28	0.31	310	<			0.509	0.055	0.04	<	2	<	12.60	2.8	1.92	47	5
699-15-15B	12/20/93	B09451	F	16.9	6.4	3.92	0.44	10.07	0.41	220	<													
699-15-15B	5/24/94	BOBX16	F	12.8	5.8	5.39	0.42	6.89	0.36	320	<													
699-15-15B	5/25/94	BOBX71	F	3.3	10.4	0.18	<	0.63	<	310	<													
699-15-15B	9/8/93	B07DM6	UF	13.5	6.6	3.16	0.47	8.92	0.55	300	<													
699-15-15B	8/18/93	B09211	UF	33.3	6.8	2.82	0.33	7.62	0.29	310	<													
699-15-15B	12/20/93	B09450	UF	23.5	6.1	1.99	0.64	10.71	0.42	220	<													
699-19-43	8/11/93	B091Y0	F	35.8	7.2	3.02	0.38	6.86	0.28	310	<			0.406	0.044	1	<	2	<	12.70	2.8	4.92	4.5	2.1
699-19-43	8/11/93	B091X9	UF	60.3	5.8	2.72	0.33	6.38	0.28	310	<													
699-19-58	9/21/93	B07DM1	F			0.8	<	5.11	0.38	200	<			0.762	0.076	0.197	0.042			17.00	3.7	3.5	4.5	3.7
699-19-58	9/21/93	B07DM0	UF	5.1	12.2	1.3	<	5.26	0.39	200	<													
699-19-88	9/29/93	B094B7	F	16	20.7	0.6	<	4.07	0.31	220	<			0.585	0.058	0.047	0.017	1.5	<	1.80	<	3.11	18	4
699-19-88	9/29/93	B094B6	UF	4	20.2	0.48	0.22	4.05	0.28	220	<													
699-2-33A	8/27/93	B07DR0	F			1.95	0.3	5.46	0.37	230	<			0.474	0.09	0.06	<	2	<	8.40	2	3.68	4.3	3.6
699-2-33A	8/27/93	B07DQ9	UF	5.5	9.6	2.86	0.41	4.7	0.36	230	<													
699-24-46	8/25/93	B07DR2	F											1.2	<	0.4	<	2	<	11.70	2.8	4.76	3.7	6.1
699-24-46	8/25/93	B07DR1	UF	6.2	8.7	0.81	0.26	5.78	0.38	230	<													
699-4-E6	8/19/93	B09220	F	1102	4.6	2.16	0.35	7.27	0.29	856	78	923	76	0.278	0.06	0.08	<	2	<	7.40	1.8	3.91	22	37.5
699-4-E6	8/19/93	B09219	UF	1077	4.1	2.76	0.38	7.56	0.31	1060	810	891	75											
699-40-33A	9/24/93	B07DM5	F			1.06	0.26	7.63	0.48	200	<			0.098	0.04	0.05	<	2	<	8.20	2.1	5.94	19	2.3
699-40-33A	9/24/93	B07DM4	UF	23.4	6.7	1.74	0.36	8.35	0.52	200	<													
699-43-88	9/28/93	B09475	F	80.8	4.6	0.5	<	3.39	0.39	220	<			0.455	0.049	0.078	0.022	1.6	<			2.6	6.4	1.3
699-43-88	9/28/93	B09474	UF	93.1	4.3	0.8	<	4.17	0.43	220	<													
699-47-46A	9/16/93	B094F9	F	10060	2.9	1.75	0.37	8.29	0.96	300	<			0.54	0.104	0.11	<	2	<	3.40	0.9	5.5	3.1	3.8
699-47-46A	9/16/93	B094F8	UF	9100	2.6	2.21	0.35	7.52	0.47	300	<													
699-48-18	8/20/93	B09228	F	11.5	7.6	1.5	0.27	5.95	0.39	210	<			0.53	0.049	0.082	0.021	1.6	<	2.01	0.86	4.25	5.3	2.6
699-48-18	8/20/93	B09227	UF	15.9	9.8	1.9	0.28	7.81	0.48	230	<													
699-49-100A	10/14/93	B09491	F	18.3	7.4	0.6	0.23	9.27	0.38	220	<			1	<	0.083	0.025	2	<			6.4	2.7	1.8
699-49-100A	10/14/93	B09490	UF	38.7	5.1	0.7	<	9.49	0.38	220	<													
699-50-28B	9/8/93	B09236	F	4245	6	1.88	0.27	4.86	0.34	190	82			0.33	0.015	0.042	0.006	1.2	<	10.00	2.2	1.87	28.2	2.3
699-50-28B	9/8/93	B09235	UF	4375	6.4	2.33	0.37	4.59	0.35	180	82													
699-50-85	8/23/93	B09244	F		9.9	0.5	<	3.18	0.26	230	<			0.565	0.064	0.044	<	1.8	<	5.03	1.4	3.01	49	4
699-50-85	8/23/93	B09243	UF	16.3	9	0.52	0.22	3.37	0.27	230	<													
699-51-75	9/28/93	B07DM9	F			0.7	<	4.6	0.31	200	<			1.009	0.242	0.4	<	2	<	20.10	4.3	3.05	5.1	1.8
699-51-75	9/28/93	B07DM8	UF	163.2	2.6	0.61	0.24	5.35	0.39	200	<													
699-54-18	10/7/93	B094D3	F	4.8	25.8	1.1	<	6.75	0.45	220	<			0.688	0.04	0.047	0.014	0.8	<			3.68	6.3	3.9
699-54-18	10/7/93	B094D2	UF	6.2	18.4	1.8	<	7	0.42	220	<													
699-55-50C	8/31/93	B09260	F	38800	4.3	0.7	0.21	5.09	0.34	230	<											3.35	42	6.2
699-55-50C	8/31/93	B09259	UF	62510	3.9	0.65	0.18	4.47	0.33	230	<													
699-55-76	6/2/94	BOBX21	F	17	5.2	1.38	0.19	4.82	0.29	310	<													
699-55-76	9/10/93	B09467	F	24.5	10	0.89	0.28	6.32	0.75	200	<	200	<					2	<	5.80	1.6	0.32	76	2.7
699-55-76	9/10/93	B09466	UF	16	7.9	1.21	0.33	5.79	0.39	300	<													
699-55-89	8/16/93	B09125	F	2.3	20	0.35	0.2	4.43	0.24	310	<	310	<	0.595	0.058	0.068	0.023	1.7	<	3.70	1.6	3.84	17.6	2.8

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Table A-2. Radionuclide Analyses of New
Groundwater Samples (Page 2 of 4)

Well	Counting Error	Ru-106 fCi/L	Counting Error	Sb-125 fCi/L	Counting Error	Cs-137 fCi/L	Counting Error	Eu-152 fCi/L	Counting Error	Eu-154 fCi/L	Counting Error	Eu-155 fCi/L	Counting Error	Ra-226 fCi/L	Counting Error	Ra-226 (Bi+Pb)		Ra-228 (Ac-228)		U-235 fCi/L	Counting Error	U-238 fCi/L	Counting Error
199-H4-45																							
699-11-45A	<	39	<	20	<	3.7	<	22	<	13	<	5.2	<	22	<	28.8	6.4	68.5	6.5	27.2	13.2	644	18.4
699-11-45A																							
699-14-38	<	50	<	17	<	1.7	<	22	<	16	<	4.1	<	25	<	25.6	32	62.4	4.5	39.4	22	1115	14
699-14-38																							
699-14-38																							
699-15-15B	<	33	<	17	<	4.3	<	36	<	24	<	8.6	<	42	<	5.9	<	21	16	6.3	<	550	<
699-15-15B	<	77	<	40	<	7.8	<	44	<	32	<	36	34	71	<	36.9	21	40.9	34	129	4	1290	21.1
699-15-15B																							
699-15-15B																							
699-15-15B																							
699-15-15B																							
699-15-15B																							
699-19-43	<	25	<	13	<	32.2	14.2	41	<	25	<	10	<	49	<	35	7.8	119	15	114	3.11	1470	20.9
699-19-43																							
699-19-58	<	50	<	26	<	49	<	13	<	9.2	<	3.3	<	14	<	93.7	4	60.3	4.7	9.2	<	750	<
699-19-58																							
699-19-88	<	48	<	27	<	2.3	<	38	<	24	<	9.2	<	44	<	7.2	<	25	14.4	9.8	<	850	<
699-19-88																							
699-2-33A	<	44	<	22	<	4.3	<	30	<	18	<	7	<	30	<	44.4	3.6	80.3	10.4	69	5.5	943	15.8
699-2-33A																							
699-24-46	<	88	<	47	<	2.8	<	61	<	44	<	21.3	71	98	<	87	18	104	36	20	<	910	<
699-24-46																							
699-4-E6	3	25	<	14	<	6.6	<	38	<	25	<	9.3	<	45	<	17.6	7.6	92	20.5	98.6	3.48	837	24.3
699-4-E6																							
699-40-33A	<	47	<	15	<	7.4	<	33	<	27	<	7.4	<	31	<	69.2	14.4	133	16	27.8	158.6	440	<
699-40-33A																							
699-43-88	<	18	<	8.8	<	4.2	<	23	<	17	<	4.4	<	27	<	9.6	<	33.4	10.2	14.5	14	442	17
699-43-88																							
699-47-46A	<	150	<	25	<	4.4	<	23	<	14	<	5.3	<	23	<	5.78	28	35.7	13.3	35.5	10	1000	14.7
699-47-46A																							
699-48-18		40	<	18	<	4.5	<	38	<	24	<	9	<	44	<	30	<	20.6	18	41.2	8.6	1390	8.1
699-48-18																							
699-49-100A	<	42	<	12	<	4.3	<	58	<	49	<	13	<	62	<	53	<	113	11	3.1	<	300	<
699-49-100A																							
699-50-28B	<	32	<	15	<	1.5	<	55	<	38	<	18	<	83	<	40.6	3.4	69.1	47	43.7	5.1	1190	6.7
699-50-28B																							
699-50-85	<	15	<	26	<	3.7	<	40	<	25	<	11	<	47	<	9	24	43.9	24	9.6	<	760	<
699-50-85																							
699-51-75	<	25	<	12	<	4.1	<	23	<	15	<	4	<	24	<	11	<	36.7	10.4	23.9	11.2	856	25
699-51-75																							
699-54-18	<	17	<	27	<	4.2	<	28	<	21	<	5.5	<	27	<	23	<	13	35				
699-54-18																							
699-55-50C	<	93	<	49	<	5.4	<	2.7	<	20	<	6.5	<	32	<	4.8	<	56.2	35.4	20	<	1300	<
699-55-50C																							
699-55-76																							
699-55-76	<	39	<	18	<	1.4	<	22	<	15	<	4.1	<	24	<	5.8	<	57.9	6.5	30.7	9.5	1000	11.6
699-55-76																							
699-55-89	<	39	<	18	<	36.9	2.9	7.7	<	5.8	<	2	<	8	<	8.49	10	81.9	22	15.3	21	658	17

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Table A-2. Radionuclide Analyses of New
Groundwater Samples (Page 3 of 4)

Well	Date	HEIS	F/UF	I-129	Gross Alpha		Gross Beta		Tritium	Duplicate	Pu-239+240			Pu-238	Am-241	Sr-90	K-40	Co-60							
				aCi/L	% Error	pCi/L	Counting Error	pCi/L	Counting Error		pCi/L	Counting Error	(1sigma)	fCi/L					Counting Error	fCi/L	Counting Error	fCi/L	Counting Error	pCi/L	Counting Error
699-55-89	8/16/93	B09126	UF	11.5	8.4	0.82	0.24	4.22	0.22	310	<														
699-57-25A	8/26/93	B07DQ8	F			1.32	0.28	6.16	0.4	230	<			0.698	0.099	0.135	0.042	2	<	2.32	0.74	5.8	4.2	4.2	
699-57-25A	5/9/94	BOBX26	F	676.9	4.3	1.53	0.19	6.04	0.33	320	<														
699-57-25A	8/26/93	B07DQ7	UF	678	3.3	0.84	0.2	5.86	0.39	230	<														
699-57-83A	9/14/93	B09268	F	6.3	7.1	1	0.21	4.08	0.3	230	<			0.395	0.04	0.056	0.017	1.5	<	3.29	0.9	3.56	7.6	5.8	
699-57-83A	9/14/93	B09267	UF	7.9	14.9	1.01	0.26	3.77	0.28	230	<														
699-62-31	8/25/93	B09276	F	62.1	7	0.5	<	5.46	0.37	230	<			0.558	0.051	0.038	0.014	1.6	<	3.60	1.2	4.04	35	2.5	
699-62-31	8/25/93	B09275	UF	67	5.1	0.5	0.23	5.52	0.39	230	<														
699-63-90	8/28/93	B07DR4	F			0.92	0.25	4.61	0.35	300	<			0.432	0.056	0.02	<	2	<	3.70	1.2	3.8	5	6.7	
699-63-90	8/28/93	B07DR3	UF	13.3	9.9	1.22	0.3	4.7	0.35	220	<														
699-66-103	9/10/93	B07DL9	F			0.6	<	4.35	0.38	220	<			0.542	0.053	0.04	<	2	<	1.40	<	3.05	7	5.5	
699-66-103	9/10/93	B07DL5	UF	7.4	12.1	0.4	<	3.79	0.29	200	<											4.3	52	27.7	
699-67-86	9/15/93	B09427	F	166.6	3.8	0.5	<	7.02	0.45																
699-67-86	9/15/93	B09426	UF	165.3	5.4	0.49	0.22	6.43	0.42	210	<														
699-73-61	5/18/94	BOBX31	F	674.6	5.8	1.02	0.16	4.62	0.28	320	<			0.09	<	0.06	<	0.07	<						
699-73-61	5/18/94	BOBX61	F	709.2	5.5	1.4	0.18	4.12	0.27	320	<														
699-78-62	5/19/94	BOBX36	F	7.1	6.6	1.45	0.19	4.9	0.3	320	<			0.025	0.011	0.013	<	0.07	<			2.34	73	3.8	
699-90-45	5/23/94	BOBX41	F	43.4	5.1	0.94	0.13	5.78	0.33	910															
699-91-46	5/13/94	BOBX46	F	9.5	6.5	1.32	0.18	4.21	0.29	5340															
699-93-48	5/13/94	BOBX51	F	43.2	3.9	1.06	0.16	3.34	0.26	2690															
699-S19-11	8/31/93	B07DL8	F			0.91	0.29	6.24	0.41	200	<														
699-S19-11	6/15/94	BOBWW6	F	6.1	7.4	1.39	0.18	5.33	0.31	310	<														
699-S19-11	8/31/93	B07DL4	UF	5.1	8.2	0.64	0.28	6.38	0.43	200	<														
699-S29-E12	5/17/94	BOBWX1	F	73.7	5.5	1.62	0.22	6.17	0.34	320	<			0.247	0.095	0.2	<	0.14	<						
699-S3-25	8/13/93	B091Y8	F	24.8	6.4	1.48	0.35	8.52	0.32	310	<			0.599	0.061	0.061	0.019	2	<			5.16	6.1	2.4	
699-S3-25	8/13/93	B091Y7	UF	11.1	9.9	1.68	0.31	9.22	0.33	310	<														
699-S31-1	9/15/93	B07DM3	F			0.76	0.26	5.02	0.34	280		60	210	<	0.649	0.07	0.268	0.043	1.5	<	2.03	0.86	3.81	7.4	1.6
699-S31-1	9/15/93	B07DM2	UF	3.1	8.7	0.73	0.24	4.77	0.34	200		60	210	<											
699-S31-E8	5/31/94	BOBWX6	F	142.9	3.5	1.59	0.23	4.67	0.29	310	<														
699-S34-E10	5/31/94	BOBX66	F	263.8	4	3.6	0.41	7.52	0.38	310	<														
699-S34-E10	5/31/94	BOBWY1	F	258.7	5	4.22	0.42	8.21	0.74	310	<														
699-S37-E11	5/11/94	BOBWY6	F	76.7	4.2	2.11	0.24	4.62	0.29	320	<			0.08	<	0.06	<	0.1	<			1.96	8.4	3.7	
699-S37-E11	5/11/94	BOBWY6	F	76.7	4.2	1.54	0.22	5.39	0.31	320	<														
699-S38-12A	5/25/94	BOBWZ6	F	96.1	4	1.46	0.19	4.26	0.28	310	<														
699-S38-12A	5/25/94	BOBWZ6	F			1.37	0.17	4.28	0.28	310	<														
699-S38-E11	5/16/94	BOBWZ1	F	127.7	3.2	2.24	0.27	8.04	0.39	320	<														
699-S41-E12	6/1/94	BOBX01	F	415.3	3.5	3.19	0.42	7.94	0.39	310	<														
699-S41-E13B	5/16/94	BOBX06	F	111.7	2.4	1.77	0.19	6.79	0.36	320	<														
699-S8-19	9/27/93	B07F16	F			0.8	<	8.81	0.53	220	<	220	<	0.508	0.054	0.116	0.025	2	<	5.00	1.6	6.66	7.3	2.4	
699-S8-19	9/27/93	B07F17	F			1.16	0.31	10.08	0.58	220	<														
699-S8-19	9/27/93	B07F14	UF	9.1	15.7	1.2	0.45	9.44	0.4	200	<														
699-S8-19	9/27/93	B07F15	UF	8	9.6	1.39	0.64	9.84	0.41	200	<														
Blank	6/3/94	BOBX76	F	4.7	6.8	0.32	0.07	0.58	<	310	<														
counting error is at 1 sigma																									

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Table A-2. Radionuclide Analyses of New
Groundwater Samples (Page 4 of 4)

Well	Counting Error	Ru-106 fCi/L	Counting Error	Sb-125 fCi/L	Counting Error	Cs-137 fCi/L	Counting Error	Eu-152 fCi/L	Counting Error	Eu-154 fCi/L	Counting Error	Eu-155 fCi/L	Counting Error	Ra-226 fCi/L	Counting Error	Ra-226 (Bi+Pb)		Ra-228 (Ac-228)		U-235 fCi/L	Counting Error	U-238 fCi/L	Counting Error
699-55-89																							
699-57-25A	<	16	<	29	<	3.8	<	36	<	24	<	8.6	<	42	<	5.9	<	21	16	52.1	9.4	1000	<
699-57-25A																							
699-57-25A																							
699-57-83A	<	87	<	46	<	4.3	<	43	<	27	<	10	<	50	<	11	47	37.6	16	19	<	944	23
699-57-83A																							
699-62-31	<	33	<	17	<	4	<	46	<	33	<	16	<	72	<	37	37	55	47	6.3	<	550	<
699-62-31																							
699-63-90	<	96	<	50	<	2.4	<	54	<	41	<	34	<	89	<	15.9	29	27	65	20	<	1300	<
699-63-90																							
699-66-103	<	81	<	42	<	3.9	<	40	<	26	<	9.5	<	48	<	33	<	40	<	18	<	1100	<
699-66-103																							
699-67-86	4.2	49	<	26	<	4	<	54	<	40	<	34	<	89	<	13.8	7.7	38.1	53	9.3	<	930	<
699-67-86																							
699-73-61																							
699-73-61																							
699-78-62	<	49	<	26	<	5	<	71	<	51	<	44	<	120	<	52.4	15	91.3	42	45.4	9.4	689	22
699-90-45																							
699-91-46																							
699-93-48																							
699-S19-11																							
699-S19-11																							
699-S19-11																							
699-S29-E12																							
699-S3-25	<	28	<	14	<	24.2	3.5	46	<	28	<	12	<	56	<	51	14	157	2.8	62.8	6.2	654	43
699-S3-25																							
699-S31-1	<	20	<	9.9	<	3.9	<	26	<	20	<	6.4	<	31	<	12.3	15	29.3	8	27.7	9.2	761	26
699-S31-1																							
699-S31-E8																							
699-S34-E10																							
699-S34-E10																							
699-S37-E11	<	63	<	24	<	6.3	<	21	<	19	<	5.6	<	28	<	54.3	15	49.7	33	8.8	<	780	<
699-S37-E11(
699-S38-12A																							
699-S38-12A(
699-S38-E11																							
699-S41-E12																							
699-S41-E13B																							
699-S8-19																							
699-S8-19	<	32	<	15	<	2.8	<	47	<	30	<	11	<	54	<	8.6	23	74	8	70	6.4	2440	6
699-S8-19																							
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counting error i																							

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